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Highway engineering

CONTENTS.

ROADS.

HISTORICAL SKETCH.

Very little is known in regard to the early history of road building. That the ancient Egyptians and Jews had roads of some kind is evident from the fact that chariots were used by both nations. The invention of paved roads is credited to the Carthaginians.

The earliest roads of which anything definite is known are those of the Romans. Thirty-one of these are said to have terminated in the city of Rome. They were built mainly for military purposes, and it is largely due to their existance that Rome maintained for so long a time her position as ruler of the known world. The manner of constructing these roads was as follows:- Two parallel trenches were first cut to mark the width of the road. Then the loose earth between these was removed until a solid foundation was reached. The earth was then replaced by proper materials, consolidated by ramming, to form a solid foundation for the covering which consisted of four layers.

The first layer (Statumen) was com-

posed of two or three courses of flat stones laid in mortar and had a thickness of about 11 inches. The second layer (Rudus) was composed of rubble masonry of smaller stones, or a coarse concrete, and was consolidated by ramming. This course had a thickness of about 8 inches. The third layer (Nucleus) was made of a finer concrete, sometimes composed of broken bricks, tile and pottery mixed with mortar, and had a thickness of about 12 inches. The surface layer (Summa Crusta) was a pavement of polygonal blocks of stone, 6 inches thick, fitted together very carefully. On rock the two lower layers were omitted. On marshy ground the road was built on a framework of timber. Sometimes the pavement was omitted, and in this case the surface layer was composed of a hard concrete made of a mixture of pebbles and mortar. Clay was sometimes used instead of mortar. The paved portion of these roads was 16 feet wide, with a footpath on either side 8 feet wide, separated from the main road by stone causeways 2 feet wide.

The Roman roads ran almost invariably in straight lines and with nearly uni-

form grades. Hills and mountains were cut through and valleys crossed either on embankments or stone arches. Mile posts were erected showing distances from Rome, and at intervals, blocks of stone were placed to assist horsemen in mounting. These roads were all more or less adorned with tombs and monuments. So solid was the construction of these roads that in some places they can be traced for miles even at the present day some of them forming the foundation for more modern roads and in some cases the original surface is still in use.

One of the oldest of these, the Appian Way, was begun in 312 B.C. It was first built to Capua, 130 miles, then the boundary of Roman territory. It was afterwards extended to Brundusium, making the entire length 342 miles. Another famous road, the Flaminian Way, extended from Rome a distance of 180 miles along the Adriatic Sea. On this road was an arch of 150 feet span and 100 feet rise. Other famous roads were the Aurelian, Emilian, Valerian and Claudian. The Roman roads were not confined to Italy alone but remains of them are to be found

in France, Germany and England. In fact wherever the Roman Legions went, there they built these almost imperishable roads.

In quite another part of the world there lived at an early period, a race of road builders, whose work rivaled that of the Romans in solidity of construction. They were the Incas of Peru and two of their roads are thus described by Prescott.

"'One of these roads passed over the grand plateau, and the other along the lowlands on the borders of the ocean. The former was much the more difficult achievement, from the character of the country. It was conducted over pathless sierras buried in snow; galleries were cut for leagues through the living rock; rivers were crossed by means of bridges that swung suspended in the air; precipices were scaled by stairways hewn out of the native bed; ravines of hideous depth were filled up with solid masonry; in short, all the difficulties that beset a wild and mountainous region, and which might appall the most courageous engineer of modern times, were encount-

ered and successfully overcome. The length of road, of which scattered fragments only remain, is variously estimated, from fifteen hundred to two thousand miles; and stone pillars, in the manner of European mile-stones, were erected at stated intervals of somewhat more than a league, all along the route. Its breadth scarcely exceeded twenty feet. It was built of heavy flags of freestone and in some parts, at least, covered with a bituminous cement, which time has made harder than the stone itself. In some places, where the ravines had been filled up with masonry, the mountain torrents wearing on it for ages have gradually eaten a way through the base, and left the superincumbent mass - such is the cohesion of the materials - still spanning the valley like an arch!

Over some of the boldest streams it was necessary to construct suspension bridges, as they are termed, made of the tough fibres of the maguey, or of the osier of the country, which has an extraordinary degree of tenacity and strength. These osiers were woven into cables of the thickness of a man's body.

The huge ropes,then stretched across the water, were conducted through rings or holes cut in the immense buttresses of stone raised on the opposite banks of the river, and there secured to heavy pieces of timber. Several of these enormous cables, bound together, formed a bridge, which, covered with planks, well secured and defended by a railing of the same osier material on the sides,afforded a safe passage for the traveller. The length of this aerial bridge, sometimes exceeding two hundred feet, caused it, confined, as it was, only at the extremities, to dip with an alarming inclination toward the centre, while the motion given to it by the passenger occasioned an oscillation still more frightful, as his eye wandered over the dark abyss of waters that foamed and tumbled many a fathom beneath. Yet these light and fragile fabrics were crossed without fear by the Peruvians, and are still retained by the Spaniards over those streams which, from the depth and impetuosity of the current would seem impracticable for the usual modes of conveyance. The wider and more tranquil

waters were crossed on balsas - a kind of raft still used by the natives - to which sails were attached, furnishing the only instance of this higher kind of navigation among the American Indians.

''The other great road of the Incas lay through the level country between the Andes and the ocean. It was constructed in a different manner, as demanded by the nature of the ground, which was for the most part low, and much of it sandy. The causeway was raised on a high embankment of earth, and defended on either side by a parapet or wall of clay; and trees and odoriferous shrubs were planted along the margin, regaling the sense of the traveller with their shades, so grateful under the burning sky of the tropics. In the strips of sandy waste, which occasionally intervened, where the light and volatile soil was incapable of sustaining a road, huge piles, many of them to be seen at this day, were driven into the ground to indicate the route to the traveller.''

The Incas travelled always on foot, but these roads are said to have been so

well constructed that carriages could have been used on them in most parts with perfect safety.

Humboldt says that ''the roads of the Incas were among the most useful and stupendous works ever executed by man.''

Like the Roman roads, the roads of the Incas were built mainly for military purposes. A system of posts for carrying despatches was in use on these roads. At intervals of about five miles, small buildings were erected in each of which were several trained runners. These runners were employed in carrying forward government despatches, which they did at the rate of one hundred and fifty miles a day.

After the fall of the Roman Empire, the roads which she had left to her provinces were allowed to go to ruin. In France and England, until the latter part of the eighteenth century, the roads were in very bad shape.

The condition of the English roads before this time is well described by several writers. In speaking of the state of the roads in England in 1685

Macaulay says - ''On the best lines of communication the ruts were deep, the descents precipitous, and the way often such as it was hardly possible to distinguish, in the dusk, from the unenclosed heath and fen which lay on both sides.'' He speaks of several cases where people lost their way while travelling in their own coaches. In speaking of the road through Wales to Holyhead, he says that at Conway it was the custom to take carriages to pieces and carry them to the Menai Straits. In some parts of England the roads were so bad that six hours were required to travel a distance of nine miles. The expense of carrying heavy loads long distances was very great, being about thirty cents a ton for every mile. Fruits would rot on the ground at one place, while at another a few miles distant, the supply fell far short of the demand. Coal was not used except near where it was mined or on the sea coast or navigable rivers, on account of the expense of hauling.

Arthur Young, in his ''Six Months' Tour'' published in 1770, says, in speaking of one of the roads - ''I know

not in the whole range of language terms sufficiently expressive to describe this infernal road. Let me most seriously caution all travellers who may accidentally purposeto travel this terrible country to avoid it as they would the devil; for a thousand to one they break their necks or their limbs by overthrows or breakings down. They will here meet with ruts, which I actually measured four feet deep, and floating with mud only from a wet summer - What therefore must it be after a winter? The only mending it receives is tumbling in some loose stones which serve no other purpose than jolting a carriage in the most intolerable manner. These are not merely opinions but facts; for I actually passed three carts broken down in those eighteen miles of execrable memory.''

Of another road he says - ''A more dreadful road cannot be imagined. I was obliged to hire two men at one place to support my chaise from overturning. Let me persuade all travellers to avoid this terrible country which must either dislocate their bones with broken pavements

or bury them in muddy sands.''

Throughout England the condition of the roads was very little improved until the latter part of the eighteenth century.

The first English road builder of any note was John Metcalf. He was very successful in constructing roads over bogs where a solid foundation could not be obtained.

After him came Macadam who, although he did not claim to be an engineer, constructed roads on scientific principals and did much to improve the condition of the English roads.

Contemporary with Macadam was Telford, who seems to have been the first trained civil engineer in England who engaged in road building.

In the United States, up to the beginning of the present century, there was hardly a good road. In the early part of the present century a large number of turnpike roads were constructed, principally in the northern states. Some of these were built at great expense and were carefully constructed. Some of the roads built in Massachusetts cost as

much as $14,000 per mile. The best roads ran from Boston to Salem, Newburyport and Providence. In New York a road was built between Albany and Syracuse at an expense of $10,000 per mile. During this period many turnpikes were also constructed in Pennsylvania, New Jersey and Maryland.

Numerous bills for national aid to roads were proposed, some of which were passed. The only work that was carried out systematically was the construction of the Cumberland National Road, which was built from Washington to Wheeling, afterwards to Columbus and Vandalia. It was proposed to extend it to Jefferson City, but this last section was not built.

Notwithstanding the great improvements that were accomplished at this time, there were yet but few good roads in the country. David Stevenson, an English engineer, who made a trip through North America in 1837 says - ''On the road leading from Pittsburgh on the Ohio to the town of Erie on the lake of that name, I saw all the varieties of forest

road making in great perfection. Sometimes our road layfor miles through extensive marshes, which we crossed by corduroy roads, formed of trees cut in lengths of about 10 or 12 feet and laid close to each other across the road to prevent the vehicles from sinking; at others the coach stuck fast in the mud, from which it could be extricated only by the combined efforts of the coachman and passengers, and at one place we travelled for upwards of a quarter of a mile through a forest flooded with water which stood to a height of several feet on the trees, and occasionally covered the naves of the coach wheels. The distance of the route from Pittsburgh to Erie is 128 miles which was accomplished in 46 hours, being at the very slow rate of two and three quarters miles an hour, although the conveyance by which I travelled carried the mails and stopped only for breakfast, dinner and tea, but there was considerable delay caused by the coach being once upset and several times mired.''

That the roads in the United States are not equal to those of Europe is

largely due to the fact that in the older countries of Europe the roads were improved before the railroad came into use, while in this country, the need of improved means of communication was not seriously felt until the railroad came, and this was so much superior to the common road for long distances that it has been brought to the greatest perfection and the common road neglected. At the present time the United States is noted for having the poorest roads of any civilized country. The descriptions of the condition of the roads in England in the seventeenth and eighteenth centurges would admirably fit many of the roads of the United States at the present time. Within the last few years, however, the people of this country have begun to realize the advantages of good roads, state legislatures have begun to take action looking toward the improvement of roads, engineers are paying more attention to the subject than formerly, and it is to be hoped that the next few years will witness a marked improvement in the common roads of this country.

ADVANTAGES OF GOOD ROADS.

Macaulay says - ''Of all inventions the alphabet and the printing press alone excepted, those inventions which abridge distance have done most for the civilization of our species.''

As we glance at the history of the world, we see that the nations that have had the highest form of civilization, have been those nations that possessed the best means of communication. One writer has said - ''Let us travel over all the countries of the earth, and whenever we shall find no facility for travelling from a city to a town, or from a village to a hamlet, we may pronounce the people to be barbarians.''

Every improvement in the highways of a country benefits the people not only socially, but also commercially. Roads are the tributaries of railroads. Nearly every pound of freight that is carried over a railroad must be hauled to and from the railroad over the common roads or streets. It has been claimed by some that the improvement of the common roads would be a disadvantage to railroads,

as some of the freight and passengers now carried by the railroads would then be carried on the highways. It is doubtless true that the railroad would lose some business in this way, such as that between cities situated but a few miles apart; but it is equally true that they would gain on the whole, on account of the increased production and general prosperity which would inevitably follow any great improvement in the common roads.

Every improvement in the roads diverging from a market increases the area tributary to the market. If on one road a horse can haul a thousand pounds, and on another two thousand pounds, it is evident that the cost of transporting goods on the latter road will be only one half of that on the former. Hence on the good road an article can be produced with profit at a distance from market twice as great as on the poor road.

The value of farm lands is determined to a great extent by the proximity to market. Land situated ten miles from market on the good road is as valuable

for agricultural purposes, as that at a distance of only five miles on the poor road. Prof. Jenks, in his ''Road Legislation for the American State'', estimates that even good dirt roads in the state of Illinois would increase the value of the farming land at least $5 per acre, making a total increase of $160,000,000 for the state.

It has been estimated that on the roads of Illinois a full load can be hauled for three months in the year, two thirds for three months and only one half a load for the other six months. From this, Prof. Jenks estimates that the loss to the state of Illinois due to the waste of animal power alone is over $15,000,000 per year.

With permanent roads, the farmer could select for going to market such times as he could most conveniently spare from his farm work instead of being obliged to go only at the time when the roads are in good condition, which usually is at that season of the year when the farm work is most urgent.

Rough roads tend to wear out vehicles much more quickly than smooth roads, and

are also very injurious to horses.

Good country roads are a benefit not only to the country through which they pass, but also to the cities and towns which serve as markets for the products of the country. For with a decrease in the cost of hauling to market, the price to the consumer will be less, the saving in the cost being divided between the producer and consumer.

The advantages of good roads may be summed up briefly as follows; - They practically shorten distances, enhance the value of land, decrease the cost of hauling articles, hence increase the profits of the producer and decrease the cost to the consumer.

REQUISITES OF A GOOD ROAD.

Before passing to the location and construction of roads, let us endeavor to get a clear idea of the requisites of a good road. We shall consider these in regard to the following points;-

1. Alignment.
2. Grade.
3. Cross-section.
4. Drainage.
5. Surface.
6. Cost.

1. Alignment. Other things being equal a road should be straight. Every deviation from a straight line increases the length, thereby increasing the cost of construction and maintenance, time and labor of travelling over it, and the wear and tear of vehicles. It is better however to deviate from a straight line to avoid steep grades which will be discussed farther on. An exception to the rule that a road should be straight ought to be made in the case of pleasure drives. Here the purpose for which the road is built is best served by deviating from the straight line as much as possible.

2. Grade. The grade or slope of a road is the ratio of the rise to the distance in which the rise occurs. It may be expressed in several different ways.

1st. As a common fraction having 1 for the numerator and the horizontal distance in which the road rises 1 foot as the denominator, thus; 1/125, often written 1 in 125 or 1 to 125.

2nd. As a certain number of feet to the mile, thus; 42.24 feet to the mile.

3rd. As a per cent, thus; 0.8 per cent sometimes written simply 0.8, though not strictly correct.

4th. As a decimal fraction the equivalent of the common fraction of the first method thus, 0.008.

Of these methods the first is perhaps the oftenest used in regard to roads, and the third, in this country at least, in regard to railroads.

Other things being equal a good road should be level, or should have a uniform grade between its termini. The resistance due to grade is equal to the load multiplied by the grade. In fig.2,

let AB represent the surface of a road with a load DE resting on it. If ab represents graphically the weight of the load, then ac will represent the component of the load perpendicular to the slope AB, or the pressure on the surface, and bc will represent the force necessary to overcome the grade. Represent ab by W, and bc by F, then since the triangles abc and ABC are similar,

$F : W :: BC : AB$ whence $F = W.BC \div AB$

or, as AC is practically the same as AB unless the slope is very steep, we have approximately $F = W.BC \div AC$ but $BC \div AC$ is the grade which we will call G. Hence we have $F = WG$

Maximum Grade. In considering the maximum grade allowable on a road, the problem is somewhat different from that in the case of a railroad. On a railroad, any grade, no matter how small, decreases the load that can be hauled, as a locomotive cannot exert for a short time a force greater than its average power. On a road the effect of a short grade is not so bad, as a horse can exert for a short time a force equal to two or three times his average power.

Let us assume that a horse can exert twice his average power for a short grade. Then if we represent by R the resistance of any load, W, on the level surface, the maximum grade allowable without decreasing the load will be found by substituting R for F in the above formula, and we have $R = WG$ or $G = R \div W$.

For a good broken stone road we shall see farther on that the resistance per ton is about 50 lbs. and on a good earth road about 80 lbs. Then for a broken stone road the maximum grade allowable will be .025 or 1 in 40, and for an earth road .04 or 1 in 25. Although it is advisable to keep the grade as low as this, yet it is sometimes impracticable, and it may be made steeper for very short distances without materially decreasing the load that can be hauled over it, for there is no doubt that a horse can for a short time, exert a force more than twice as great as the usual amount.

The investigation we have just been making applies to a load ascending, let us now see what the maximum grade should

be from the consideration of a descending load. If possible the grade should not be steeper than that at which a load is just on the point of rolling down hill by its own weight alone, called the grade of repose. This is $R \div W$, the same as we found for the maximum grade ascending, or .025 for a broken stone, and .04 for an earth road. With a steeper grade than this there is a certain amount of danger from the load pressing upon the horses. With these grades a horse can safely trot down hill.

From this investigation we see that the smoother the road surface, the easier the grades should be . A steeper grade can be used on an earth road than on a broken stone road without decreasing the load that can be hauled on the level road. The grades we have given here are what we should strive to obtain. It is often necessary however to use steeper grades.

The maximum established by the French government Engineers was 1 in 20, but this was at a time when the surface of roads was not as smooth as at the present time.

The maximum used by Telford on the Holyhead road, built through the mountains of Wales, was 1 in 30, except in two cases where 1 in 22, and 1 in 17 were used.

The maximum on the Simplon road over the Alps is 1 in 22 on the Italian, and 1 in 17 on the Swiss side, becoming 1 in 13 in one case.

The cost of maintenance of a nearly level road is much less than that of one with steep grades. This is due to the increased wear caused by the feet of horses in going up and down steep hills, and by the use of trigs behind the wheels, to keep them from rolling, when horses stop to rest in ascending a hill.

It has been claimed by some that a level road is not as easy for a horse as one with undulating grades. There seems however, to be no foundation for this theory and it is discarded by modern writers. The level road is the best for the horse.

We have said that a road should be as nearly level as possible. This is strictly true as far as traction is concerned, but there is another thing that

must be considered, and that is drainage. For drainage there should be a certain minimum longitudinal slope to prevent water standing on the surface. A slope of 1 in 125 is recommended as the minimum.

3. Cross-section. The cross-section may be considered under the following heads,-

(1) Entire width or Right of Way,

(2) Surfaced width or Roadway,

(3) Shape of Roadway.

(1) The entire width of a road, sometimes called the Right of Way, should be sufficient to accomodate any increase in traffic which is likely to occur. The width should be sufficient to allow for the construction of good side ditches, and footpaths where necessary, and for side slopes of cuts and fills. About the only disadvantage of increasing the width is in the cost of the land.

The entire width of the roads in many of the western states, where the land is divided into sections, is 4 rods or 66 feet.

The French roads are divided into four classes, ranging from 33 to 66 feet in

width.

Telford's Holyhead road has a width between fences of 32 feet on flat ground and 22 feet along steep ground and precipices.

The United States National Road has a total width of 80 feet.

In the state of New York public roads are not less than 3 rods or 49 1/2 feet wide.

(2) The surfaced width of a road,which we will designate as the roadway, should be as small as will accomodate the traffic. The wear of a road is due to two causes, traffic and weather. Sir J.Macneill estimated that, on the average, twenty per cent. of the wear of a broken stone road was due to the weather. The wear due to the traffic is practically the same, whatever the width of the road, within reasonable limits, but the wear due to the weather is proportional to the width. Hence it is advisable to keep the road as narrow as possible, as every extra foot of width means an increase not only in cost of construction but also in cost of maintenance.

The width of a roadway should seldom

if ever be less than enough to allow two vehicles to pass each other easily, which requires about 16 feet. This is enough for all roads except the most important where there is a very large traffic. For these a width of 23 feet, which will allow three, or 30 feet,which will allow four vehicles abreast, may be used. Near large cities a farther increase may be necessary to 40 feet or even more. On sharp curves the width should be slightly more than on straight lines.

Sometimes where broken stone is used for a covering, the center of the road for a width of 16 feet is covered with the stone, or road metal as it is called, and the sides or wings are left with the natural earth surface. It is doubtful, however, if this is advisable, as vehicles in passing from the earth surface to the stones will carry, in wet weather, a great amount of mud, thereby injuring the surface of the stone covering.

The Roman roads had a width of 12 to 16 feet.

The French roadways range in width from 16 to 22 feet.

The roadway of the United States National Road is 30 feet.

(3) The shape of the cross-section of the roadway has always been a disputed point. For ease of travel, a perfectly level cross-section is of course the best, but , to allow the water which falls on the surface to find its way readily to the ditches, it is necessary to give a certain amount of crown, that is, to make the center a certain amount higher than the sides. Two forms of cross-section are used, as shown in Fig. 1. One of these, A, consists of two straight lines joined by a short curve at the center, the other, B, consists of a continuous curve from side to side, usually an arc of a circle. Both of these forms have their advocates among engineers, but the former seems to carry the weight of opinion.

The chief objection to the curved section is that the center is nearly flat, thus preventing the water from flowing off readily. Another objection sometimes made to the curved section is, that the slope is so steep near the sides that vehicles will seek the center

to prevent overturning, thereby causing excessive wear in one place. This objection, however, is hardly worth considering as, with a good surface, the amount of crown is so slight that there is no danger from this source. The only point worth considering is that of drainage.

Fig.1 A shows a half section of a road 30 feet wide with a transverse slope of 1 in 30, and Fig.1 B, a half section of a road 30 feet wide, having the same crown as in Fig.1 A, but formed by an arc of a circle. Fig.1 C, in which the two are placed together, shows how slight the difference is between them.

The slope shown in the figure, 1 in 30 is one that is often given to a broken stone road. It was used by Telford on the Holyhead road. Macadam used 1 in 36 and even 1 in 60. For a rough road 1 in 20 may be used. The transverse slope should increase with the grade or longitudinal slope so as to prevent the surface water from running very far down the road before being discharged to the sides.

Where a road curves sharply it is best

to have a single slope falling toward the inside of the curve to counter-balance the centrifugal force. This form is often used on steep side-hill roads.

4. Drainage. One of the most important requisites of a good road is thorough drainage. Without proper drainage a road cannot be kept in good condition. We may consider the question of drainage in regard to -

(1) The water which flows toward the road,

(2) The water which falls on the surface of the road,

(3) The water which finds its way beneath the surface.

(1) The water which flows toward the road may be either in the form of streams, which flow perpetually, or it may be the water from the surface of the ground, which comes only at the time of storms or of the melting of the snow.

The streams must be provided for by culverts or bridges which will allow them to pass under the road and follow their natural course.

The storm water from the surface of the ground does not usually come in a

concentrated form like the streams, but must be collected in side ditches parallel to the road and carried along to some natural water course as quickly as possible. These ditches should if possible, have a slope of 1 in 125.

(2) The crowning of the surface of the road to prevent water standing on it has already been discussed. The water from this source is received by the side ditches and carried away with that from the surface of the ground.

When there is a footpath at the side of the road there should be a gutter between it and the carriage way, and the main ditch should be outside the footpath. The water from the road surface will then be received by the gutter and carried, at short intervals, through small drains under the footpath to the ditch. The footpath should be given a slope toward the gutter to allow the water to flow off.

(3) It is very often the case that water collects beneath the surface of a road either by soaking through the covering or from springs below the surface. This should be carefully considered and

provision made for removing it thoroughly. For this purpose under-drains of stone or tile (the construction of which will be described later) are often required. These should lead into the side ditches which should be made deep enough to receive them. When these under-drains are used, the drain under the footpath , connecting the gutter with the side ditch, is not needed, but the water from the gutter is carried directly into the sub-drains by a vertical shaft.

5. Surface. In order that the force required to draw a load shall be as small as possible, the road should have a smooth and hard surface.

The resistances to be overcome in drawing a load over a level road are -

(1) Collision,

(2) Friction.

(1) Collision. On a rough road, or a road covered with loose stones, a great amount of force is expended in lifting the wheels over the projections and stones which they encounter.

In Fig.3, let P be an obstacle over which it is necessary to draw a wheel

carrying a load, W. Let F be the force required to do this work, the amount of which we wish to find.

Taking moments of the forces F and W about the point E, we have

$F.ED = W.EB$ or $F = W.EB \div ED$

But $ED = R - h$, R being the radius of wheel and h the height of the obstacle, and $EB = \sqrt{R^2 - (ED)^2} = \sqrt{R^2 - R^2 + 2Rh - h^2} = \sqrt{2Rh - h^2}$

Hence $F = W\sqrt{2Rh - h^2} \div (R - h)$

If $R = 24$ inches, and $h = 2$ inches, and $W = 1000$ lbs. then $F = 436$ lbs. Now the force required to draw this load over a smooth broken stone road is 25 lbs. or only one seventeenth that necessary to draw it over an obstacle 2 in. high.

F, in the above demonstration, is the force required to draw the wheel over the obstacle provided it is just starting from a condition of rest. As a wheel moves along with a certain momentum, the effect of such obstacles is only to partially destroy that momentum.

If the obstacle is a loose stone the effect upon the road is very injurious, not only on account of the impact of the wheel in descending, but also on account

of the tendency of the stone to slide along the surface, due to the force, F, which acts parallel to the surface.

(2) Friction. Journal friction, or the friction of the wheel upon the axle is dependent entirely upon the construction of the vehicle, and has nothing to do with the construction of the road.

Surface friction is the friction which exists between the tire of the wheel and the surface of the road. It is caused by the wheel sinking into the surface. On a road covered with mud or sand this friction is very large.

When the surface of a road is covered with a layer of soft mud, or loose sand or gravel, so that the wheels sink through to the hard surface, the friction due to the soft layer is independent of the amount of the load, as the depth to which a wheel will sink is the same, whatever the amount of load, being the thickness of the soft stratum. If there is no hard sub-stratum the wheels will sink to a depth proportional to the load, and the resistance to be overcome will increase accordingly.

The elasticity of the surface of a

road, which allows the wheel to sink into it, but causes it to assume its original smoothness after the wheel has passed, may be considered as a form of surface friction analogous to the last form considered.

It is impossible to calculate the resistance due to friction on a level road The only way in which it can be determined is by experiment. Experiments have been made by the use of an instrument called a dynamometer, which is made on the principle of the spring balance, and is interposed between the horses and the vehicle. The power required to draw the vehicle is registered on a dial. Such an instrument was used by Sir John Macneill and is described by Parnell in his Treatise on Roads, Appendix No.1. As the result of his experiments, he has given the following arbitrary formulae in which R is the force required to move the vehicle, W is the weight of vehicle, w is the weight of load, all expressed in pounds, v is the velocity in feet per second, and c is a constant, depending on the nature of the surface.

For a stage wagon

$$R = \left[(W+w) \div 93\right] + (w \div 40) + cv$$

For a stage coach

$$R = \left[(W+w) \div 100\right] + (w \div 40) + cv$$

The value of c is given as follows,-

Timber surface	2
Paved road	2
Well made broken stone road, dry and clean	5
Well made broken stone road, covered with dust	8
Well made broken stone road, wet and muddy	10
Gravel or flint road, dry and clean	13
Gravel or flint road, wet and muddy	32

In France, extensive experiments were made by Morin to determine the resistance on different surfaces. The conclusions which he arrived at as the result of these experiments may be stated briefly as follows:-

The resistance to traction is directly proportional to the load and inversely proportional to the diameter of the wheel.

The destruction of the road is greater with small wheels than with large.

Upon soft roads the resistance decreases as the width of the tire in-

creases, but upon paved or hard macadamized roads the resistance is practically independent of the width of tire beyond a width of 8 to 10 centimeters (3 1/4 to 4 inches).

Upon soft roads the resistance is independent of the velocity, but upon paved or macadamized roads, it increases with the velocity, above a velocity of a meter a second. At a walking pace it is the same for carriages with or without springs.

At a walking pace the resistance upon a well paved road is about three-fourths that upon the best macadamized roads; at a trot the resistances are equal.

The following table which has been prepared from the results of the experiments of Macneill, Morin and various other authorities will readily show the advantage of a hard and smooth road surface.

Table of Resistance
to Traction on Various Surfaces.

Description of Surface	Resistance in Terms of Load
Soft grass land	1/7
Ordinary earth road	1/10

Good earth road	1/30 to 1/22
Sandy road	1/12
Newly laid gravel	1/10
Ordinary gravel road	1/16
Good gravel road	1/30 to 1/26
Newly laid metal	1/5
Ordinary broken stone road	1/25
Good broken stone road	1/50 to 1/40
Cobble stone pavement	1/30 to 1/15
Ordinary stone block pav't	1/40 to 1/25
Good stone block pavement	1/70 to 1/40
Good wood pavement	1/50
Plank road	1/70 to 1/40
Asphalt pavement	1/133 to 1/65
Stone tramway	1/170
Iron tramway	1/200

6 Cost. In considering the cost of a road there are four elements that should be taken into account.

(1) Cost of Construction.

(2) Cost of Maintenance.

(3) Cost of Operating.

(4) Revenue.

(1) The cost of construction includes the cost of making the location, the cost of grading, the cost of structures, the cost of ditching and surfacing, and any other expenses required to make the

road complete for travel.

(2) The cost of maintenance includes all the expenses of keeping in repair and renewing structures and surface, keeping ditches open and maintaining the road in every particular in the condition it was in when the construction was finished.

(3) The cost of operating is the cost of drawing the traffic over the road, which is made up of the cost of labor of men and draught animals, the interest on the investment in vehicles and harnesses and the wear and tear on them.

(4) Revenue is the amount of money received by the owner as the result of the traffic.

The requisite of a road as to cost is, that the revenue should always exceed the interest on the cost of construction, plus the cost of maintenance and operating, by as large an amount as possible.

In the case of a railroad the stockholders construct, maintain and operate the road and receive revenue from the transportation of freight and passengers.

With the highway the case is never quite the same as with the railroad.

Perhaps the nearest approach is in the case of the toll road, where the toll company constructs and maintains the road, but does not operate it. The revenue derived by the company is in the shape of toll received from those who use or operate the road. As far as the toll company is concerned the end sought is to make the revenue as much larger than the interest on the cost of construction, plus the cost of maintenance as possible. The cost of operating does not have any direct bearing on the case. It has, however, an indirect influence, as the less the cost of operating, the greater will be the traffic, and hence the revenue derived therefrom.

In the case of the common road the public constructs, maintains, and operates the road, and derives the revenue indirectly from the increase in the value of articles moved. In this case the proposition, that the revenue should exceed the sum of the cost of maintenance and operating, and the interest on the cost of construction, should be observed. It is very seldom that it is possible to estimate, with any great degree of accu-

racy, the cost of operating and the amount of revenue to be derived in the case of a road, nevertheless these should always be taken into account in considering the advisability of building a new road, or in deciding between different routes. In considering the advisability of improving an old road, over which a fixed amount of freight is carried, the case is simpler. The cost of construction should be considered as the cost of making the improvement. The cost of maintenance may be taken as the increase or decrease in cost of maintaining due to the improvement. The cost of operating will be a negative quantity, and will be the difference between the cost of operating the road before and after the improvement. The revenue may be considered as the difference between the revenue before and after the improvement, or in this case nothing. It will then be more economical to make the contemplated improvement if the interest on the cost of construction, plus (or minus) the increase (or decrease) in the cost of maintenance, is less than the saving in cost of

operating.

To illustrate this, let us take the case of an earth road 5 miles long, having a traffic that requires the work of 12 horses and 6 drivers for 300 days in the year. Suppose it is proposed to macadamize the road at a cost of $5000 per mile, and we wish to find out whether it would be economical to do so, provided there were no increase in the traffic. Let us take the resistance on a macadamized road as two-thirds that on an earth road. Then the traffic of the road under consideration could be carried on by 8 horses and 4 drivers on a macadamized road. Then , if the labor of a man and pair of horses is worth $3 a day, the saving in operating would be $1800 per year. Assume that the maintenance of the macadamized road costs $50 more per mile per year than that of the earth road. Then the entire yearly cost of the improvement, with interest at 5%, will be the interest on cost of construction, $1250, plus increased cost of maintenance, $250, a total of $1500. Hence the net yearly saving will be $300.

The case , however, is seldom as simple as this, as an improvement in a road almost invariably leads to an increase of traffic, hence an increase of revenue, and this increase should be given due weight in the investigation.

LOCATION.

Having obtained an idea of the requisites of a good road, we are now prepared to consider the location.

The requisites that should be taken intoaccount in making the location are, that the road should be straight, that it should be level, and that the revenue minus the sum of the three items of cost should be a maximum.

It is evident that in the ordinary case it is impossible to satisfy all these conditions. It is generally impossible to make a road straight and level without making the cost excessive.

The condition which should be given the greatest weight is that which relates to the cost, and indeed, if this is properly considered, the others may be neglected.

Probably the most uncertain element to be taken into account, in determining upon the best location, is the amount of traffic that may be expected. Yet it is best to make an estimate of this as carefully as possible.

The work of locating a road should consist of three parts,

1. Reconnaissance.
2. Preliminary.
3. Location.

1. The reconnaissance consists of a careful and thorough examination of all the ground over which there is any probability that the road ought to pass.

The first thing for the engineer to do is to procure the best map of the region that can be obtained. This will usually show the course of the streams, and from these the position and direction of the ridges can be approximately traced upon the map. With this map, and no instruments except the aneroid barometer, a pocket compass, and a hand level, the engineer makes a thorough examination of the region through which the road is to be located. The ground should be crossed from both directions, as the features of a piece of country often appear quite different as seen from different standpoints.

The reconnaissance should take note of low places in a ridge which the road has to pass over, of favorable points to cross streams, of quarries or deposits of gravel where suitable material may be

found for the surface of the road, in fact, of all the features of the country which can in any way influence the location of the road. In addition to this the engineer should obtain all information possible, that will in any way assist him in making an estimate of the amount and class of traffic that may be expected.

2. The preliminary. The reconnaissance will generally narrow the investigation down to one or more general routes, of which it will then be necessary to make the preliminary survey.

This is made with the transit, for producing straight lines and measuring angles, the 100 ft. chain or tape, for measuring distances, and the level and rod, for obtaining elevations. A careful preliminary survey should be made of each of the routes which the reconnaissance indicates as possible locations. The preliminary survey, in each case, should occupy as nearly as possible the position that the location will have if made on the same general route. Stakes should be set at intervals of 100 ft. along the line, numbered consecutively

0, 1, 2, etc. from the starting point.

A careful record of distances and angles should be kept in the note book, so that a map can be made. A convenient scale to use for such a map is 400 feet to the inch. The map should show streams, buildings, property lines and, where the ground is irregular, contour lines for a short distance on each side of the line.

Levels should be taken along the line, so that a profile can be made. The profile should, for convenience in comparing with the map, have the same horizontal scale. The vertical scale should be much greater than the horizontal, so as to show prominently the inequalities of the surface. The profile, in addition to the elevations of the surface of the ground, should show the elevation of high and low water at the crossings of streams. Upon the profile should be drawn the grade line, in such a position that the cuts and fills will be as nearly equal as possible without making the grades too steep.

If preliminaries have been run in more than one place, approximate estimates of

the cost of construction, maintenance, and operating should be made, and serve as a basis for determining on which line the final location should be made.

Let us take a very simple case as an illustration.

Suppose it is required to connect by a system of roads three towns, A, B and C, Fig.4. This can be done in either of three ways.

1st. By building the road from A to C through B.

2nd. By building the straight road from A to C, with a branch from B to D.

3rd. By building roads from A to B, from B to C, and from A to C.

From data furnished by preliminary surveys of all these lines we are to determine which is the proper system to build.

Let us assume, for simplicity, that the cost of construction is $5000 per mile, and the cost of maintenance $100 per mile per year, on all the lines. Assume also that a traffic of 6000 tons may be expected in each direction between A and C, and 3000 tons in each direction between A and B, and B and C,

and also that the grades are such that a pair of horses can draw a load of 2 tons 30 miles a day.

Call the labor of a man and pair of horses worth $3 a day, and with interest at 5% the following table will give the cost per year of each system.

	Interest on Construction.	Maint.	Operating.	Total.
1st	$1250	$500	$4500	$6250
2nd	1375	550	4500	6425
3rd	2250	900	3900	7050

From this comparison it is evident that the most economical system to build is the 1st.,AB and BC.

Adifferent arrangement of the towns, a greater cost of construction per mile on one line than on another, a greater cost of hauling loads on one line, due to steeper grades, or a different assumption in regard to the traffic, would all tend to complicate the problem and give a case more nearly like that which the engineer usually has to deal with.

3. Location. The approximate position of the line having been decided upon

from a comparison of preliminaries, the next step is to make the location.

If the map of the preliminary survey has been carefully made and shows the contours of the surface, the location can be quite closely decided upon by a study of the map and profile. The end to be sought is to decrease the cuts and fills, and improve the grades as shown by the preliminary, as much as possible.

The located line should consist of straight lines connected by curves, the radius of which should not generally be less than 50 feet. Sometimes where the deflection angle is quite small, no curve is used, the angle being allowed to remain.

As in the preliminary survey stakes should be set along the line 100 feet apart.

A map of the location should be made showing the position of the line with reference to all property through which it passes, together with the location of buildings thereon. This map should also show the point of crossing and angle made with streams, other roads or railroads.

A profile should be made showing the

ground and grade lines, the elevation of high and low water at crossings of streams, the location, length and general character of all bridges on the line, and size and material of culverts. If known, the class of material to be encountered in cuts should be given. The profile should also show the approximate quantity of material in each cut, fill and structure.

CONSTRUCTION.

In this section we shall include the making of cuts and fills, and the building of structures. The preparation of the covering we shall reserve for a subsequent section.

Before the actual work of construction is begun, the first thing to be attended to is the acquisition of the land required for the road. This should be obtained by purchase if it can be bought for a fair price. Sometimes the owner of a piece of land will not sell at any reasonable price. In such a case the land can be obtained under the law of Eminent Domain, or by ''condemnation'' as it is often called. By this law the land can be taken after a certain legal process, and such a price paid for it as may be fixed by a commission appointed for the purpose.

The work of construction can be done by day labor hired by the town or county building the road, or by contract. The latter method is usually the more economical, and fully as satisfactory if the work is in charge of a competent engineer.

If the work is to be done by contract, a written contract should be made and signed and a bond given by the contractor for the faithful performance of the work. The contract should give the prices agreed upon for moving earth and rock, for constructing bridges, culverts drains, etc. and should specify the time when the work is to be completed and the dates when payments are to be made. It is usual to reserve a certain per cent (usually 10%) of the value of work done when payments are made, until the final payment after the completion of the work. The contract should also include specifications of the manner of doing the work.

The actual work of construction we shall consider under two heads,

1. Grading.
2. Structures.

1. Grading.

The entire width of the road should first be cleared of brush and trees unless it is decided to leave some for shade. On the question of the advisability of having trees along the roadside, there is a difference of opinion.

It is evident that they exclude the rays of the sun from the road and prevent it from drying quickly after rains. This might not be a very serious objection in the case of a broken stone road that is properly drained, as very little moisture would remain on the surface. In the case of the ordinary earth road it is desirable to have the mud dry as soon as possible, and anything that tends to prevent it from so doing is to be avoided.

Another objection to having trees very near a road is that the roots, as they grow, are very likely to cause a considerable amount of injury to the road covering, and to extend their extremities into the joints of drains. Yet they add much to the attractiveness of a road and, in the case of pleasure drives, they are almost indispensable. The objections to them will be to a great extent done away with, if they are allowed to remain only along the outside edges of the right of way. If allowed only on the north side, they will be a benefit in winter, in northern latitudes, by keeping snow from drifting across the

road, and affording protection to travellers.

After the clearing has been done the line should be ''cross-sectioned''. Cross-sectioning consists in ascertaining the cut and fill at points so selected that the amount of excavation and embankment can be calculated, and in setting stakes to indicate to those who are to do the grading the cut and fill to be made. Cross-sections should be taken on regular ground at each station, or 100 feet apart, on irregular ground or sharp curves they should be closer together. At each cross-section, in addition to the center stake, a slope stake should be set on each side to indicate the edge of the slope. Each of these stakes should be marked with the vertical distance of the top of the embankment above, or the bottom of the excavation below the ground at the stake. For his own convenience, it is well for the contractor to fix a pole in the ground at the center stake, where a fill is to be made, with the top at the elevation above the ground, indicated by the stake.

The slope to be given to the sides of the embankment and excavation deserves some attention.

Some kinds of earth will stand at a steeper slope than others. It is usual, however, to give a slope of 1 1/2 horizontal to 1 vertical to all earth embankments. Some kinds of earth will not stand permanently at this slope but require as flat a slope as 2 to 1. Embankments made entirely of rock are sometimes given a slope of 1 to 1.

In excavations the slope is usually made 1 1/2 to 1 in earth, and as steep as 1/4 to 1 or 1/5 to 1 in rock. Some earth will stand a slope of 1 to 1. It is recommended by some that the slope on the south side of the cuts be made as flat as 2 to 1 to allow the sun to shine upon the road as much as possible.

Before the grading is begun the roots should be grubbed up between the slope stakes and wherever ditches are to be dug. It is best to remove roots under all embankments, although it is sometimes thought to be unnecessary under those over 3 or 4 feet high. But in any case the stumps should be cut close to

the ground.

The method of doing the grading will depend largely upon the character of the profile and the provisions of the contract. Where the ground is quite regular the grade line will usually be a foot or two above the ground and the grading will consist in making ditches along the sides of the road, and using the earth excavated to form the roadbed. When there are cuts and fills, the fills should be made with material taken from the cuts, provided it does not have to be hauled too great a distance. The distance to which it is economical to haul material from a cut to make a fill, rather than to waste from the cut and borrow for the fill, will depend upon the class of material to be hauled, and the power used to haul it.

When the excavation exceeds the embankment it is necessary to waste the excess, either by widening the fill at the mouth of the cut, or by forming a waste bank. When it is necessary to make such a bank, a little time spent in making an approximate estimate of the amount of earth to be wasted, and in

setting stakes to mark the line of slope of the bank, will be more than repaid by the better appearance of the bank. All material wasted on the surface of the ground near a cut, should be far enough back from the top of the slope to prevent it from washing back into the cut.

The tools used for doing the grading will depend largely upon the distance the material has to be hauled. When the haul is very short, as when the material is taken from the sides of the road, the shovel and wheelbarrow are sometimes used.

The drag scraper,(Figs.5 and 6) which holds from 1/10 to 1/4 of a cubic yard of earth, and is drawn by a pair of horses, is more commonly used for short distances, either in borrowing from the sides, or in hauling from cut to fill.

The drag scraper is filled by raising the handles and allowing the edge to run under the earth. When filled, the edge is raised by pressing downward upon the handles. When the scraper reaches the point at which the earth is to be dumped the handles are raised until the edge catches in the ground and the scraper is

overturned. In this condition it is drawn back to the place of loading.

On work where there is a nearly uniform fill for some distance, as is often the case on the western prairies, the "New Era Grader" has been used to advantage. This machine, which requires twelve horses, is drawn along where the ditch is to be made, plows a continuous furrow, and delivers the earth upon the embankment by means of a wide belt, which moves at right angles to the line of draught. A harrow should follow upon the embankment to break up the lumps and level the earth left by the grader.

When the haul exceeds 75 or 100 feet, the wheel scraper should take the place of the drag scraper. (Figs. 7, 8 and 9.) This holds from 1/3 to 1/2 of a cubic yard and is drawn by a pair of horses.

In filling the wheel scraper an extra pair of horses, called a "snatch team" is hitched ahead of the regular team. The wheel scraper is filled by first raising a lever which lowers the scraper into position to fill. The scraper is then filled by raising the handles in the same manner as with the drag scraper

When filled, the scraper is raised from the ground to the carrying position by pressing down the lever. To dump the load, the lever is raised until the edge of the scraper catches in the ground, when the scraper revolves. The driver usually loads the drag scraper, while the wheel scraper requires an extra man, called a ''scraper holder'', for this purpose. One scraper holder can attend to the loading of several scrapers. A plow drawn by two or more horses is used to loosen the earth for both the drag and wheel scrapers.(Fig.10.)

When the length of haul exceeds about 1000 feet, it is generally economical to use wagons or carts, instead of scrapers. Both of these are loaded by a force of shovelers. The wagon has four wheels and its bottom is made of poles or light timbers, resting longitudinally upon the sills without any fastening. To unload, the poles are raised one at a time by two men, one at each end of the wagon, thus allowing the earth to run through. Its capacity is about 1 cubic yard.

The cart usually has two wheels and is

drawn by one or two horses, its body is balanced on a pivot so that it can be easily emptied by tipping back. Its capacity is from 1/2 to 1 cubic yard.

The cost of handling earth is about the same with either cart or wagon. In some localities the wagon, and in others the cart, is used for the same class of work.

With a haul of 1000 feet or over, where the amount of earth to be moved is quite large, a track is often laid and a train of cars, drawn by a horse, is used to advantage. These cars hold about 1 cubic yard each.

Sometimes the amount of work may be so great as to warrant the use of a steam shovel to do the excavating and a small engine to haul the cars.

The solidity of the embankment will depend largely upon the method of making it.

Wheel barrow work makes the poorest embankment, as it is very soft and settles very much after completion.

The drag scraper, when the earth is hauled from the sides, makes the firmest embankment, as the horses compact it by travelling over every part of it, as the

work goes on

An embankment made with the wheel scraper, wagon, or cart, where the fill is made by hauling from the cut, is inferior in solidity to that made with the drag scraper, as the horses usually travel near the center of the embankment instead of over the whole surface.

The ''New Era Grader'' makes a very good embankment if the earth is properly levelled by a horse harrow.

Embankments made with cars are not as solid as those made with scrapers, carts or wagons.

A bank built up in layers is preferable to one made by building on at the end. Embankments made with the drag scraper can be best made in layers, while those made with the wheel scraper. wagon and cart, by hauling from the cut are usually kept about up to grade and extended at the end. The wheel scraper and wagon are usually driven over the end and unloaded on the slope, while the cart is backed to the edge and the contents dumped over.

A bank built up in layers should be constructed as in Fig.11, and not as in Fig.12, the sides always being kept

higher than the edges. This will tend to prevent any sliding from taking place.

A bank should always be kept at the proper width as it is built up, as it is difficult to make new material stay in place on such a slope as is shown in Fig.13, which is the shape an embankment will often take if proper care is not used.

When embankments are built along a side-hill, it is sometimes necessary, if the hill is very steep, to cut the original surface into steps as shown in Fig. 14, to prevent the embankment from sliding.

Where an embankment is required over a swamp, it is sometimes difficult to get a good foundation. If the soft material is not very deep, and is underlaid by a hard sub-stratum, it is in some cases advisable to remove the soft material and start the embankment on the hard layer; in other cases it is better to dump the earth for the embankment directly upon the surface, and let it sink through the soft material and come to a bearing upon the sub-stratum, continuing the filling until a solid bank is raised

above the surface. Sometimes it is necessary to build an embankment across a swamp where the soft material is so deep that some other method of construction has to be resorted to. In such cases a method which has been used with great success, is to build a mattress upon the surface, of two layers of brushwood bound in bundles, the bundles in the lower layer extending in a longitudinal direction and those in the upper in a transverse direction. Upon this the embankment is constructed. In all cases where the embankment is built over swampy places, deep and wide ditches should be dug on either side.

When cuts and fills are nearly completed the engineer should set at each station three grade stakes. These are driven one at the center and one at each edge of the roadbed, with their top at the exact elevation of the required surface of the roadbed. In setting these stakes the fact should be borne in mind that although earth when freshly dug will occupy a larger space than before excavation, it will after a time shrink so as to occupy a less space than in its

orignal state and the stakes should be set to allow for any settlement. Rock will of course occupy a larger space in embankment than before being excavated and broken up.

It is necessary to take account of this when balancing the cuts and fill on a profile, or estimating the amount of waste or borrow in a piece of grading.

Below is given a table showing the amount of embankment that can be made from 1 yard of different materials in excavation.

Rock	1.75 cu.yds.
Gravel or sand	.92 cu.yd.
Clay	.90 cu.yd.
Loam	.88 cu.yd.
Vegetable surface soil	.85 cu.yd.
Puddled clay	.75 cu.yd.

For finishing the slopes of cuts a tool,called a mattock, is used,being similar to a pickaxe with a wide blade.

For obtaining the proper slope a right angled triangle is often made of boards, as shown in Fig.15, the hypothenuse being at the proper slope when the legs are vertical and horizontal. This can be brought to the proper position by a

level bubble inserted in the horizontal leg, or a plumb line suspended on the vertical leg.

On the up hill side of a cut there should always be a ditch to receive and carry away the surface water which would otherwise run down over the slope of the cut. This ditch should be so far back from the edge of the slope as not to cause the earth between it and the slope to cave in. In the bottom of a cut on either side of the roadbed there should be a ditch to receive and carry to the mouth of the cut, the water which falls on the slopes and on the surface of the road.

To prevent washing, the side slopes of embankments and excavations can be sown with grass seed, a thin coating of loam having been first spread over the surface.

The excavation of rock deserves a little attention. When an occasional boulder is encountered one or two holes drilled by hand and charged with dynamite will usually be sufficient to break it in pieces that can be easily handled.

When a ledge of rock of some magnitude

is encountered, it is best, if the ledge is hard, to use drills, operated by steam or compressed air. Several holes should be fired at once by a battery, as in this way a great saving will be effected over the old method of firing each hole independently by a fuse. A book that gives quite an amount of useful information on the subject of blasting is the ''Quarryman and Contractors Guide'' written by Arthur Kirk of Pittsburg, Pa.

Sometimes a ledge of soft shale may be encountered which is not hard enough to require blasting, but can be broken up with pickaxe and crowbar.

In some of the mountain roads of Europe it has been necessary to build tunnels.

The depth at which it is economical to make a tunnel in place of an open cut, will vary to a considerable extent with the class of material encountered and the width of roadbed, and a careful study ought to be made of each special case. It may in some cases be as small as 30 feet and in others as great as 60 feet.

2. Structures. The structures which

we shall consider are,

(1) Retaining Walls.

(2) Culverts.

(3) Bridges.

(4) Drains.

(1) A retaining wall is a wall built to resist the pressure of earth filled in behind it.

Retaining walls are sometimes used on side hill work, or where land is so valuable that it is more economical to build them, than to buy a wide strip on each side for the side slopes.

The pressure that a retaining wall has to resist is that of the earth which lies above a plane, coinciding with the surface of the slope which the earth would assume if the wall were removed.

In Fig. 16, if A B represent the slope which the earth would take if unsupported then the triangular prism of which A B C is a section is held in place by the wall B C D E. When the earth rises above the top of the wall, as in Fig.17, the wall is said to be surcharged and the section A B C F is held in position by the wall.

A retaining wall may fail by sliding

or tipping at the base, or at any horizontal joint.

The forces acting upon a wall of this kind are the earth pressure and the weight of the wall itself. It is evident that if the resultant of these forces falls outside the face of the wall at any joint, the wall will be overturned. The weight of any given wall can be easily calculated, but the theory of the earth pressure is quite complicated.

One of the chief causes of the failure of retaining walls is the presence of water in the earth behind them. This may increase the pressure upon the wall in either of two ways, 1st. by freezing and expanding, and 2nd. by mixing with the earth and reducing it to a semi-liquid state. To prevent water from remaining behind the wall, openings should be left in the masonry near the base to allow it to escape. It is well to fill in directly behind the wall with broken stone, to allow the water to find its way quickly to the base.

(2) Culverts. When the water that drains from a small area has to be car-

ried under a road, a culvert of some kind must be provided.

A common formula for deciding upon the size of opening for a culvert is

$A = C\sqrt{M}$, in which

A = Area of opening in sq.ft.

M = Drainage area in acres.

C = 1.0 for level country.

= 1.6 for compact hilly country.

= 4.0 for rocky mountainous country.

If the size of drainage area cannot be estimated closely enough without, a very close approximation can be obtained by making a rough traverse, using a pocket compass to determine courses, and pacing the distances. The traverse can then be platted on cross-section paper and the number of squares counted to obtain the area.

It is best, however, not to stick too closely to the formula but to modify it in any special case by all the information that can be obtained such as the size of opening where the same stream is crossed by other roads, the elevation of high water, and the experience of the inhabitants of the region.

Culverts may be made of (a) Wood, (b)

Stone, (c) Concrete or Beton, (d) Brick, (e) Pipe.

(a) Wooden culverts are very extensively used. They are not very expensive and are not very durable. They are sometimes made of 2 or 3 inch plank and with an opening of 1 sq. ft.or less, but it is questionable whether an opening much less than 2 feet square should be used, as a culvert of smaller opening is likely to become filled with refuse and is difficult to clean out. They may be built as large as 4 feet high by 6 feet wide.

The manner of construction is clearly shown in the drawings, Figs.18 and 19. Sills of 8x12 inch timber, laid flat, should be bedded below the level of the bottom of the side ditches, at a distance of 5 or 6 feet from each other. The walls, which should have a thickness of 6 or 8 inches, should be drift bolted to the sills, which are notched down to receive them. When the walls exceed 3 feet in height, struts should be put in between them at mid-height, at intervals of 8 or 10 feet to prevent the sides from being forced in by the earth.

The cover should be spiked or drift bolted to the top of the walls, and should have a thickness of from 3 to 8 inches, depending on the width of the culvert.

Where the water runs with considerable velocity, it may be necessary to protect the bottom of the culvert, in which case a floor of 2 inch plank, spiked to the sills, will answer the purpose. In any case the earth should be carefully tamped around the sills and under and behind the walls.

The chief objection to wooden culverts is their short life and, although they may be cheaper than those of more durable material, it is doubtful whether it is policy to build them except on unimportant roads. When the time comes for renewing, then the road has to be torn up, and the road surface injured and traffic impeded. It is of course difficult to estimate the inconvenience occasioned in this way in dollars and cents, but such things should always have weight in deciding on the relative economy of different classes of structures. When the amount of money available for

construction is limited, it may be necessary to build less substantial structures than true economy would dictate.

(b) Stone culverts. In a country where stone is very plenty, stone culverts are built very cheaply, being usually constructed of an inferior quality of masonry.

There are two forms of stone culverts, box and arch.

Box culverts may range in size from 2 feet square up to a span of 4 feet and a height of 6 feet. When the width is only 2 feet the walls may be carried up straight to the top as in Fig.20, but when it exceeds this, it is best to draw the walls in toward the top until they are only 2 feet apart, as in Fig.21. The covers should have ample thickness, 1 foot being usual for a span of two feet. The walls should have a thickness of from 2 to 3 feet and be set on a foundation course about 1 foot thick. With the larger sizes, wing walls are used to hold back the slope, but they are often omitted on the small ones.

When the width exceeds 4 feet it is best to use an arch culvert (Fig.22) and

sometimes for a less width this form is used. The construction of the foundation and walls of the arch culvert is similar to that of the box. The top consists of an arch, usually semi-circular in form, about 12 inches thick. The wing walls sometimes have a batter of 1 to 2 inches to the foot.

Stone culverts are usually built of rubble masonry, sometimes of squared masonry.

Box culverts may be laid with or without cement.

The sides and walls of an arch culvert are generally laid in cement, and the arch should always be.

The bottom of stone culverts should have a pavement from 8 to 12 inches thick, of cobble stone or stone chips set on edge, and at each end a large stone should be set in the ground to the depth of 2 feet to prevent washing.

It is usual to rip-rap the space between the wing walls at either end for the same purpose.

(c) Concrete or Beton culverts.

Within a few years concrete or beton formed of a mixture of cement, sand, and

stone, have come to be used for many purposes in the place of stone. It could be used for building all sizes of culverts where the stone that can be obtained is of an inferior quality not suitable for constructing walls and arches, but making a good concrete.

A mixture of sand and cement is sometimes used for repairing old masonry, the crevices being filled, and the surface covered with a layer about 4 inches thick. A very interesting description of its use in repairing culverts on the N.Y. L.E.& W. R.R. is given in the Transactions of the American Society of Civil Engineers, Vol .10, p.291.

In building of concrete or beton, wooden forms are used to mould the material to the proper shape.

(d) Brick is sometimes used for building culverts where stone is not plenty and a material more durable than wood is required. Brick culverts are made of practically the same form as stone arch culverts. Sometimes the walls of an arch culvert are built of stone and the arch of brick,as a better arch can be constructed of brick than of stone un-

less carefully cut.

(e) Pipe. For culverts of small capacity pipes are often used. Under high embankments cast iron pipes are preferable. Cement and vitrified sewer pipes are sometimes used. A second quality of vitrified sewer pipe which will make a very fair culvert can often be bought very cheaply. Cement pipes are often very brittle and it is doubtful if their use is to be recommended.

When an iron pipe is used it is quite common to build a wall of stone around each end of it, and to rip-rap or pave the entrance and outlet(Fig.23). In some cases wing walls have been constructed as for stone culverts. Two pipes may be used side by side when one would not have sufficient capacity.

(3) Bridges.

When the road crosses a stream or swamp where a culvert would not have sufficient opening, or when it passes over a railroad, a bridge of some kind is necessary. Bridges may be constructed of

(a) Wood

(b) Iron

(c) Iron and Wood combined

(d) Stone, Brick or Beton

(a) Wooden bridges may be either simple beams or trusses.

Beam bridges consist of two or more beams which carry the floor and are supported at their ends on piles, trestles, or abutments of masonry.

The span may be from 15 to 20 feet. Fig.24 shows a common way of constructing a pile bridge of a single span when the fill is not over 4 or 5 feet high. The piles are driven,three or more for each support, are cut off at the proper elevation and capped with timbers 12x12 inches. The stringers rest upon the caps and are drift bolted to them. The earth back of the piles is held in place by planks spiked to the piles.

When the height of the embankment exceeds 4 or 5 feet this form of construction is not advisable on account of the increased pressure of the earth on the planks and piles. In such cases the form of construction shown in Fig.25 is used. A slope is given to the end of the embankment and the piles are driven into the slope. The first stringers rest on a 12 x 12 inch timber, and this

rests on pieces of plank 3 or 4 feet long firmly bedded in the embankment. Sway bracing of plank bolted to the piles should be used as shown in Fig.25.

In rocky ground where it is impossible to drive piles, trestles are used instead. Fig.26 shows the cross-section of a trestle as commonly constructed. It consists of four posts, two of which are vertical, and two battered. These posts rest upon a sill usually 12 inches square, and this rests upon mud sills one under each post.

Trestles are also commonly used in place of pile bridges when the height exceeds about 25 feet. In this case the construction is the same as in Fig.26, except that piles are driven where possible to take the place of the mud sills

When the length of the posts exceeds about 30 feet it is customary to make a "double decked" trestle by putting in an extra horizontal timber at mid-height, which forms a cap for the lower posts, and a sill for the upper posts.

In trestles, longitudinal bracing is required between bents. This is usually of plank, spiked to the posts.

A bridge is often built of beams supported on abutments of masonry(Fig.27). When the span is too great for a simple beam,a trussed beam,Figs.28 and 29,may be used. A better form of construction, where there is plenty of space below,is shown in Figs.30 and 31. A still more common form of construction is shown in Figs.32 and 33,called the king and queen trusses. For spans of 50 to 60 feet the truss shown in Fig.34 is often used. For longer spans,the Howe, or sometimes the Pratt truss, is commonly used.

(b) Iron. The simplest form of an iron bridge consists of two or more rolled I-beams,which carry the flooring and are supported on abutments of masonry. Fig. 35 shows the cross-section of an I-beam, which is a solid beam of iron, consisting of a web, A, and two flanges, B and C. Spans of 25 or 30 feet may be bridged in this way, but for greater spans, up to 70 or 80 feet, plate girders, built up of plates and angles are generally used. The section of such a girder is similar to that of an I-beam,consisting of a web and two

flanges. The web is a thin rolled plate of iron to which are riveted the flanges each consisting of two angle bars, or twoangle bars and one or more plates, as shown in Fig.36.

When a longer span is required, it is necessary to use one of the various forms of trusses.

A truss consists of a web composed of vertical and diagonal, or all diagonal members; some of which are in tension and some in compression, an upper chord which is in compression, and usually a lower chord which is in tension.

In Figs.37 to 42, pieces subject to compression are indicated by a heavy line, those subject to tension by a light line, those subject to both tension and compression by a double line, and counters, which are not in action when the bridge is symmetrically loaded, by a dotted line.

The following are some of the simple forms of trusses,

Howe truss.(Fig.37) In the Howe truss the tension members of the web are vertical, and the compression members inclined.

Pratt truss (Fig.38). In the Pratt truss the tension members are inclined and the compression members are vertical.

Warren truss (Fig.39). In the Warren truss both the tension and compression members are inclined at the same angle.

Post truss (Fig.40) In the Post truss the tension members are inclined at an angle of 45 degrees, and the compression members at an angle of 18 degrees 26 min. with the vertical.

Fink truss (41), and Bollman truss (Fig. 42). In both these trusses the lower chord is omitted. The tension members are inclined and the compression members vertical.

The last three are seldom if ever built at the present time, although there are still some of them in existance.

Various other forms are used but they are nearly all modifications of one of these simple trusses.

(c) Combination of Wood and Iron. Bridges have been built with the upper chord, and sometimes the compression members of the web, of wood, and other parts of iron. Such bridges are, how-

ever, very little used at the present time.

(d) Stone bridges consist of an arch, side walls or abutments, and usually wing walls. Stone arches are not uncommon on the roads of some of the European countries, but have not been used very much in this country. Brick is sometimes used instead of stone for such bridges, and in France beton has been used to some extent.

(4) Drains.

Covered drains may be required to carry to the side ditches water which collects under the road covering; (Figs. 43, 44, and 45), to carry the water from the gutter under the foot path to the side ditches, (Fig. 46), to carry water from the upper to the lower side of side hill roads, (Fig. 47), or to take the place of open ditches in cuts.

When the soil consists of clay or other impervious material, so that any water which may soak through the road covering can not readily find its way to the side ditches, or where the ground is naturally swampy and wet, a thorough system of under drains is necessary.

These drains are usually constructed running from the center of the road to the ditches, in plan like the letter V with a very obtuse angle, as shown in Fig.43, the angle pointing toward the ascent when the road is on a grade. They are often called ''mitre''drains. The distance apart of these drains will depend upon the character of the soil, varying from about 20 feet to a distance equal to that between side ditches. Another method is to lay the drains parallel with the line of the road, using one or more, according to the nature of the soil, and connecting them by cross drains with the side ditches at intervals of 200 or 300 feet.

The depth to which these drains should be laid depends upon the severity of the climate, as it is advisable to keep them below the frost. In England they are usually laid at a depth of about 2 feet below the surface while in the northern part of this country 3 1/2 to 4 feet is necessary.

They may be constructed of various kinds of material such as stone, brick or tile. Fig.48 shows the cross-section

of a drain made of flat stones arranged so as to give a square opening for the water. Fig.49 shows a drain of broken stones thrown into a trench loosely, often called a ''blind'' drain. Figs. 50, 51 and 52 are drains formed of bricks arranged in different ways. Figs. 53 and 54 are tile drains. Tiles of 2 to 4 inches in diameter are often used for this purpose. The drain should be covered with a layer of sod with the grass side down, brush wood, hay, or other suitable material, to prevent dirt getting into it. A strip of burlap is sometimes used with satisfactory results as it is so thin that no settlement of the material above takes place when it decays. The trench above the drain should be filled with broken stone or gravel to allow the water to percolate freely.

To carry the water from the gutter into the side ditch, when there is a footpath, drains should be used at intervals of 75 or 100 feet. For these, drain tile is most commonly used. These are unnecessary when the road is underdrained, the water from the gutters being

carried to the under drains by vertical shafts as shown in Fig.45. These shafts should be covered with gratings to prevent leaves and sticks from getting into the drains.

For carrying water from the upper to the lower side of side-hill roads, tile or stone drains should be constructed at intervals of 200 or 300 feet so that the ditch will not be worn by water running in it for a long distance.

In cuts it is sometimes advisable to dispense with open ditches. In such cases covered drains are often built of stone as shown in Fig. 54 a.

ROAD COVERING.

Having considered the forming of cuts and fills and the building of mechanical stmuctures, we are now prepared to turn our attention to the road covering.

Roads may be divided with reference to the material of which the surface is formed as follows,-

1. Earth.
2. Broken Stone.
3. Gravel.
4. Corduroy.
5. Plank.
6. Charcoal.
7. Shell.

1. Earth Roads.

In most parts of this country the road surface is nothing more than the natural soil. In some places the character of the soil is such that it makes roads that are excellent during the greater part of the year.

There is no doubt but great improvement could be made in the ordinary earth road by proper construction and maintenance. The first and most important thing to be sought is good drainage. Deep ditches on either side, with a system of subdrains where necessary, will

do much toward improving the ordinary earth road.

A mixture of two kinds of earth may often be made which will result in a material much superior for road purposes to either alone. A dry sandy road may thus be improved by the addition of clay, or a clayey road by the addition of sand as clay and sand will form a mixture that will consolidate with a hard, smooth surface, not easily worked into mud.

The use of a roller is another means of improving the surface of an earth road, as it consolidates the material so as to make it smoother and harder, and less impervious to water. A road leveller may be used to advantage in the spring, after the road becomes dry, but is so rough as to make travel unpleasant and difficult.

2. Broken Stone Roads.

The subject of Broken Stone Roads we shall take up under the following heads,

(1) Macadam Roads.
(2) Telford Roads.
(3) Quality of Stone.
(4) Stone Breaking and Stone Breakers
(5) Road Rolling and Road Rollers.

(6) Modifications of Macadam and Telford Roads.

(7) Maintenance and Repair of Broken Stone Roads.

(1) Macadam Roads.

The first scientific road building in England was done by Macadam in the early part of the present century. His work consisted, not in building new roads, but in repairing old ones.

He found the road surface composed of a mixture of earth and large stones. He dug up the surface, separated the stones from the earth, broke them into small angular fragments, and relaid them on the road. The traffic was then allowed to pass over the road and the ruts formed by the wheels were filled, as soon as they appeared, by men with rakes, until the road became consolidated.

The stones were broken with hammers by persons sitting. A large stone was used as an anvil on which to lay the stones to be broken, and the hammer used weighed about 1 pound, and was provided with a short handle.

Macadam at one time directed that the stone should be broken into fragments

not exceeding 1 inch in any dimension. He afterward used 6 oz. as the maximum weight of the stones, which corresponds to a 1 1/2 inch cube, the longest dimension of which is 2 1/2 inches. In his later practice, he used 3 oz. as standard weight, corresponding to a 1 1/4 inch cube, whose longest dimension is 2 inches. He claimed that a large stone in any part of the road was injurious.

The thickness of the layer of broken stone, or road metal, as he laid it, varied from 4 to 10 inches according to the traffic. He thought that 10 inches of well consolidated material was enough to carry any traffic. Fig.55 shows the cross-section recommended by him for the repair of a road in 1819. He insisted that the stones should be clean. He said ''every road is to be made of broken stone without mixture of earth, clay, chalk, or any other matter that will imbibe water and be affected with frost, nothing is to be laid on the clean stone on pretence of binding; broken stone will combine by its own angles into a smooth, solid surface that cannot be affected by vicissitudes of weather or displaced

by action of wheels which will pass over it without a jolt and consequently without injury.""

His theory was that the natural soil, if kept in a dry state, could carry any load that might come upon the wheels of a vehicle; and that the road covering was simply a water tight roof to keep the natural soil free from moisture.

Macadam claimed that a road built over soft ground cost less for maintenance than one built upon a ledge, and mentioned the case of a road on which the cost of maintenance of a section over a morass was to that of a section upon lime-stone rock as 5 to 7.

(2) Telford Roads.

Telford, who was a contemporary of Macadam, differed from him in the manner of constructing his broken stone roads. He first set by hand a layer of rough paving. On this he spread a layer of fine broken stone, similar to that used by Macadam, and the surface he covered with a thin layer of gravel, as a binding material, to hold the stones in place and to hasten their consolidation.

The following are the specifications

in accordance with which he constructed a part of the Holyhead road:-

''Upon the level bed prepared for the road materials, a bottom course or layer of stones is to be set by hand in form of a close firm pavement: the stones set in the middle of the road are to be seven inches in depth; at nine feet from the center, five inches; at twelve feet from the center, four inches; and at fifteen feet, three inches. They are to be set on their broadest edges lengthwise across the road, and the breadth of the upper edge is not to exceed four inches in any case. All the irregularities of the upper part of the said pavement are to be broken off by the hammer, and all the interstices to be filled with stone chips firmly wedged or packed by hand with a light hammer; so that when the whole pavement is finished, there shall be a convexity of four inches in the breadth of fifteen feet from the center.

The middle eighteen feet of pavement is to be coated with hard stones to the depth of six inches. Four of these six inches to be first put on and worked in

by carriages and horses; care being taken to rake in the ruts until the surface becomes firm and consolidated, after which the remaining two inches are to be put on.

The whole of this stone is to be broken into pieces as nearly cubical as possible, so that the largest piece, in its longest dimensions, may pass through a ring of two inches and a half inside diameter. The paved spaces on each side of the eighteen middle feet are to be coated with broken stones, or well-cleansed strong gravel, up to the foot path or other boundary of the road, so as to make the whole convexity of the road six inches from the center to the sides of it; and the whole of the materials are to be covered with a binding of an inch and a half in depth of good gravel, free from clay or earth."

There were two important points in which Telford's system differed from that of Macadam. 1st. in the use of the foundation pavement of large stones, and 2nd. in the use of a binding material.

Although Telford is usually given the credit of having first proposed this

form of construction, practically the same thing was used by Tresaguet, a French engineer as early as 1775.

By him the earth was prepared for the foundation parallel to the surface of the finished pavement, instead of level as was done by Telford. With this exception their methods of construction were almost identical.

(3) Quality of Stone.

Various kinds of stone are used for making broken stone roads. The qualities desirable are hardness, thughness, readiness of fragments to bind together, and resistance to the action of the weather.

The best stone for a broken stone road is a trap or basalt.

Granite is not as good, especially when coarse-grained, as it is brittle and decomposes easily.

Syenite makes a good road when fine-grained.

The soft limestones are not suitable, but some of the harder varieties make a fairly good road. Limestones have the quality of binding readily.

The sandstones are, in general, too

soft.

Flint and quartz rocks are too brittle although very hard.

For the bottom layers any of the inferior kinds of stone may be used when good stone has to be brought from a distance, the surface layer only being formed of the best variety obtainable. The softer varieties are often used for the lower layers on account of the less cost of breaking. Slag, or refuse from furnaces has been used to some extent.

The French engineers give the following coefficients of quality of materials used on the national roads, as the result of their experience.

Coefficients of Quality of Road Materials.

Granitic gravel	23.8
Quartz gravel	21.4
Trap	20
Quartz	10 to 25
in one instance	4.8
Basalt	12 to 20
Porphyry	10 to 20
in one instance	5
Quartzite	11 to 18
Devonian schist	16

Schist	4 to 12
Sandstone	12 to 16
Granite	6 to 20
generally	10 to 12
Syenite	12
Gneiss	9 to 12
Silicious pebbles and gravel	8 to 19
in one instance	6
Silex	8 to 16
Chalk flints	7 to 11.6
Silicious limestone	6 to 18
generally about	10 to 12
Compact limestone	14
Magnesian limestone	12
Carboniferous limestone	9
Oolitic limestone	5 to 12
Lias limestone	5 to 10
Jurassic limestone	5 to 8
Limestone	5 to 12
Mean of all France	10.63

When it is necessary to decide between different kinds of stone, their relative value for road metal may be ascertained to a certain extent by a series of tests. Boulnois recommends the following:-

(1) Ascertain from local persons such as masons, quarrymen, and others, their opinion of the qualities of the stones

in the neighborhood.

(2) Make a trial of the stone for toughness. This can be done by setting a good stone-breaker to work upon a heap of the stone as quarried and carefully watching how much he can break in an hour.

(3) Ascertain what power the stone has to resist abrasion. This is done in France by putting the broken metal into a revolving cylinder and then carefully noting by weight what the cubes lose by contact with each other. Another plan may be adopted by pressing the stone against a grindstone with a uniform pressure, and noting the loss caused by such contact.

(4) The power to resist compression may be easily ascertained by placing small cubes in an hydraulic press and noting under what pressures each cube will crush.

(5) The effect of weather is not easily ascertained artificially, although it is suggested that a good test may be by soaking the stone in a saturated solution of sulphate of soda; and then on exposure to the air, if soft, it is said

the stone will disintegrate as if under the action of thaw succeeding frost.

Another method which has been suggested for testing the effect of weather, is to soak the stone in water and submit to freezing, by artificial means if necessary, and note the tendency to disintegration upon thawing. The relative porosity, as shown by the per cent of water absorbed by specimens of different stone, would probably be some guide as to the relative effect of the weather upon them. The only really satisfactory test, however, of the value of any stone for road metal is obtained from the use of the stone in the road.

(4) Stone Breaking and Stone Breakers

In the time of Macadam and Telford the stone was broken by hand, as we have seen, by persons sitting, using a one pound hammer with a short handle. Later a hammer weighing two pounds, with a handle about three feet long, was used by men standing.

The screenings were separated from the larger stones by using a several pronged fork instead of a shovel for handling the broken stone. The prongs were about

an inch and a half apart.

The size of the stone was tested by a ring with an inside diameter usually 2 1/2 inches. When the stone was gauged by weight instead of size, the inspector used a small balance scale for the purpose.

At the present day stone is almost invariably broken by machinery.

There are two distinct classes of stone breakers that are used quite extensively. In one of these the stone is broken between iron jaws one of which has an oscillating motion; in the other the stone is broken by being pressed against the inside of an iron frame by a spindle having a gyrating motion.

The construction of these will be seen by referring to the figures.

Fig. 57 shows a section of the first form or the "Blake" style of stone crusher, as manufactured by the Farrel Foundry and Machine Co. of Ansonia, Conn. F F is a cast iron frame, H is the fixed jaw, and J is the movable jaw which is hung upon the bar K. P P are plates of chilled steel between which the stones are crushed. E is a pitman connecting

the eccentric at C with the toggles, G G, which give the jaw, J, an oscillating motion. W is a wedge, raised or lowered by the nut, N, to regulate the size of the stone. R is a rubber spring which is compressed by the forward motion of the jaw J, and aids its return. B is the fly wheel, and D the driving pulley.

This crusher is made in several different sizes as shown in the table on page 100, which is taken from the catalogue of the manufactures.

The 15" by 9" size is the one most used for road work.

Fig.58 shows one of these crushers mounted on wheels so as to be easily moved from place to place for road building and repairing.

Fig.59 shows a perspective sectional view of the second form of stone breaker, the Gates Rock and Ore Breaker made by the Gates Iron Works of Chicago, Ill.

Q Q is the frame which has an inclined diaphragm for discharging the broken stone. C, the top, has three openings for receiving the stone to be broken, and also has a bearing in the center for the main shaft, G. The base, 3, forms a bear-

F A R R E L & M A R S D E N S T O N E C R U S H E R S.

No.	Size of Receiving Capacity in inches.	Product per hour 2 inch size in cu.yds.	Total Weight in lbs.	Proper Speed.	H.P. Required.	Price.
1	3 x 1.5	Laboratory	100	250	.5	$ 40
2	6 x 2	1	1200	250	4	150
3	10 x 4	3	4900	250	6	275
4	10 x 7	5	8000	250	8	500
5	15 x 9	8	15500	250	15	750
6	15 x 10	9	16000	250	15	800
7	20 x 8	10	11200	250	15	650
8	20 x 10	10	18300	250	20	1050
9	12 x 30	16	33000	250	30	2000
10	15 x 30	20	35000	250	30	2000
11	36 x 24	Preparatory				

G A T E S   R O C K   B R E A K E R S.

Size.	Each Receiving Opening in inches.	Total Weight in lbs.	Capacity per hour 2.5 inch ring in tons.	Revolutions of Driving Pulley.	H.P. of Engine Recommended.	Price
00	2 x 4	500	Laboratory.	700	.5	$ 125
0	4 x 10	3100	2-4	500	4	400
1	5 x 12	5500	4-8	475	8	600
2	6 x 14	7800	6-12	450	12-15	800
3	7 x 15	13500	10-20	425	20-30	1200
4	8 x 18	20000	15-30	400	30-40	1900
5	10 x 20	27000	25-40	375	40-50	2500
6	11 x 24	36000	30-60	350	50-60	3500
8	16 x 42	89000	100-150	350	125-150	7000

ing for the gear, L, which has attached to it an eccentric box, D. This eccentric forms a bearing for the lower end of the shaft, G and imparts a gyrating motion to it, which crushes the stone between the fluted cone, F, and the liners E. The gear, L, is driven by the pinion M, which is keyed to the shaft, X. The shaft, X, is driven by the pulley, TU, by means of the break pin, W, which projects into the hub, V. This pin is so proportioned that it will break before any other part of the machine does.

The table on page 101 is from figures given in the catalogue of the manufactures.

Fig. 60 is another cut of this breaker.

Fig 61 shows one of these breakers mounted on wheels.

For screening broken stone a revolving cylindrical screen formed of sections having circular holes of different sizes is generally used. This receives the broken stone directly from the crusher and separates it into the different sizes required. Figs. 58 and 62 show two forms of revolving screens.

Stone broken by hand is superior, for

road metal, to that broken by machinery as it is more nearly cubical in form, but as it costs at least twice as much it is very seldom used.

The practice of separating the stone into different sizes, although generally followed, is opposed by some as not only useless, but as an injury to theroad, as it causes a large per centage of voids in the road covering, thereby allowing the surface water to run through to the soil beneath. Stone broken to a 2 inch gauge contains, on the average, about 45% of voids when spread loosely. In a well consolidated road the voids are as much as 25% of the entire volume. It is a question worth considering whether it is not better to use a proportion of smaller stone to partly fill these voids, than to allow them to be filled with mud which will ultimately be the case.

(5) Road Rolling and Road Rollers.

There are three methods of rolling a road,-

1st. By the Traffic.

2nd. By Horse Rollers.

3rd. By Steam Rollers.

In the time of Macadam and Telford

roads were always consplidated by the traffic, as rollers were not brought into use until a much latter period.

The gorse roller was introduced in France in 1833.

It was not used in England until after 1842, as Sir J.F.Burgoyne, in a paper written that year, describes the practice of rolling in France and Germany, and recommends its introduction into England.

The steam roller was not used until after 1860. The first one used in Paris was about 1864, in England about 1873.

There are various forms of horse rollers. One consists of a hollow cast iron cylinder which can be filled with water to increase the weight. The roller is mounted in a circular frame which allows it to be drawn in either direction without turning. Such a roller 4 1/2 feet in diameter and 5 1/2 feet long weighs about 4 tons when empty.

A roller used in the New York City Department of Parks, was composed of two cylinders of cast iron 7 feet in diameter and each 2 1/2 feet long, mounted abreast in a timber framework. In the

ends of the cylinders were openings into which broken stone or gravel could be placed to increase the weight. This roller, empty, weighed 6 1/2 tons, and could be loaded to 12 tons.

Another form of roller, which is used quite commonly, consists of cast iron discs placed side by side on an axle. These discs are about 4 inches thick and are of two diameters varying by about 8 inches.

The best method of consolidating a road is by a steam roller. Several kinds of steam rollers are in use in this country. The Aveling & Porter, an English Roller, Fig.63, is made in various sizes from 10 to 20 tons. The most common size in use for all classes of work is the 15 ton roller.

The Harrisburg Roller, Fig.64, made at Harrisburg, Pa. is made in three sizes. 10, 12, and 15 tons.

The Springfield Roller, made at Springfield, Ohio, ~~is shown in Fig. 65.~~ ~~It~~ is made in three sizes, 10, 12 1/2 and 15 tons.

The Lindelof Roller made at Erie, Pa. is largely used for rolling asphalt

pavements.

In England, the rollers in most common use are those made by Aveling & Porter, and by Thos.Green & Son.

The disadvantages of compacting a road by traffic are,

1st. The length of time required.

2nd. The necessity of keeping men continually at work filling the ruts while the consolidation is going on.

3rd. The great waste of power occasioned by hauling loads on the rough, loose surface.

4th. The excessive wear of vehicles.

5th. The cruelty to horses.

6th. The unnecessary wear of the road metal which takes place before the road is consolidated.

7th. The inferiority of the road when consolidated, occasioned by the corners and edges of the stones wearing off, leaving them more or less rounded.

The disadvantages of horse rolling are

1st. The horses feet tear up the road surface.

2nd. The angular stones are injurious to horses feet.

3rd. It is impracticable to use a roll-

er heavy enough to consolidate the road as it can be done with a steam roller, on account of the number of horses that would be required to draw it.

4th. Horse rolling is slower and more expensive than steam rolling.

A weight per inch run of nearly 500 lbs. may be obtained with a steam roller while it is impracticable to get a weight per inch of much more than one half this amount with a horse roller.

In a paper read before the American Society of Civil Engineers in 1879, Mr. E.P.North gives his experience with traffic, horse and steam rolling as follows,-

""Some refuse Westchester marble (a very soft rock) was delivered on some of the roads at about 25 cents per cubic yard, and hand broken in place at the rate of about 1 cubic yard per hour. A portion was rolled before any traffic went over it, some after about two weeks of traffic and some after six weeks; of the rest, part was horse rolled and part compacted by wheels; the quality of the stone, tnaffic, etc were very nearly the same; that not rolled by the steam roll-

er soon wore into holes, the first mentioned is, after standing two winters, in very fair surface; the others decreasing in the order in which they are mentioned. This difference is so noticable that anyone could pick out their sequence as mentioned.''

A word may be said here with reference to binding material. Macadam, as we have seen, would not allow the use of binding material in any form, while Telford used it invariably. The necessity of binding material on a road compacted with a roller is well shown by the experience of Mr.Wm.Grant on the roads of the New York Central Park. He says,''At the commencement of the Macadam roads, the experiment was tried of rolling and compacting the stone by a strict adherance to Macadam's theory - that of carefully excluding all dirt and foreign material from the stones, and trusting to the action of the roller and the travel of teams to accomplish the work of consolidation. The bottom layer of stone was sufficiently compacted in this way to form and retain, under the action of the rollers, (after the compression

had reached about its practical limit) an even and regular surface, but the top layer - with the use of the heavy roller loaded to its greatest capacity - it was found impracticable to solidify and reduce to such a surface as would prevent the stones from loosening and being displaced by the action of wagon wheels and horses feet. No amount of rolling was sufficient to produce a thorough binding effect upon the stones, or to cause such a mechanical union and adjustment of their sides and angles together as to enable them mutually to assist each other in resisting displacement. The rolling was persisted in, with the roller adjusted to different weights up to its maximum load, until it was apparent that the opposite effect from that intended was being produced. The stones became rounded by the excessive attrition they were subjected to, their more angular parts wearing away, and the weaker and smaller ones being crushed. The experiment was not pushed beyond this point. It was conclusively shown, that broken stones of the ordinary sizes and of the very best quality for wear

and durability, with the greatest care and attention to all the necessary conditions of rolling and compression would not consolidate in the effectual manner required for the surface of a road while entirely isolated from, and independent of other substances. The utmost efforts to compress and solidify them while in this condition, after a certain limit had been reached, were unavailing."

The best material for a binder is probably stone screenings from the crusher. Sand or gravel are also good for the purpose but clay or loam should never be used. A thorough watering of the road will hasten consolidation.

The sides of a road should be rolled first, so that when the rolling is done on the higher parts the material will not spread out at the sides for lack of support.

In regard to the length of time that the rolling should be continued, it is difficult to give any fixed rule. In Paris the custom has been to continue the rolling until the surface is so hard that a single stone placed upon it will be crushed under the roller.

The following extract, from a paper read by Mr. Deacon before the Institution of Civil Engineers in 1879, will give an idea of the amount of rolling required. "The Author has tried many methods. Under a 15 ton steam roller, preceded by a watering cart, 1200 yards of trap-rock macadam without blinding, can only be moderately consolidated by twenty-seven hours coutinous rolling. If blinded with hard rock chippings from a stone breaker, the same area may be moderately consolidated by the same roller in eighteen hours. If blinded with siliceous gravel from three-fourths inch to the size of a pin's head, mixed with about one-fourth part of macadam sweepings obtained in wet weather, the area may be thoroughly consolidated in nine hours."

(6) Modifications of Macadam and Telford Roads.

Many modifications of the methods of Macadam and Telford have been used, some differing quite materially and others only slightly from theirs.

A modification of the Telford road (Fig. 66) used by Sir John Macneill on the Highgate Archway Road near London in

1828, had a foundation consisting of a six inch layer of concrete composed of one part of Roman cement, one part of sand, and eight of stone. In the surface, while it was yet soft, grooves four inches apart were made with a triangular piece of wood extending from the center to the sides, both to hold the road metal, and to allow the water which might percolate through it, to flow off.

On this foundation, as soon as it had set, was spread a layer of broken stone six inches thick. This form of construction has been very little used, but where the ground is very wet it has its advantages.

Another modification of the Telford construction has a foundation of rubble stone laid flat instead of on edge, as in Fig. 67. This form of foundation has been used to some extent, but is considered inferior to the pavement. It was common in France prior to 1775 when Tresegaut recommended setting the stones on edge.

The principal objection to it is, that, as the large stones are not wedged in place as in the pavement, the wheels in

passing over them, cause a motion among them which keeps the surface in a loose condition. Macadam speaks of a road over Breslington Common in England, where flag stones had been laid on the soil as a foundation for the road covering. The surface was kept in a loose state by the motion of the stones, which were found, when the road was dug open, to be turned upon their edges.

Fig. 68 shows a form of construction that was used on 5th. Avenue, New York. It had a Telford foundation eight inches thick, a layer of two and one-half inch stones three inches thick, a layer of two inch stones four inches thick, a layer of coarse screenings one inch thick, and a layer of fine screenings one half inch thick. The broken stone and screenings were of trap rock.

Fig. 69 shows a form of construction that was used in Chicago until within two or three years. It has a Telford foundation seven inches thick. On this is spread a seven inch layer of broken stone that has passed through a two and one-half inch circular hole, with no stone smaller than will pass through a

one and one half inch circular hole. This is covered with a layer of stone screenings, which, after being thoroughly rolled, shall have a thickness of one-half inch

On this is spread a layer of crushed granite, the largest to pass through a one and one-half inch , and the smallest through a three-quarter inch circular hole. This is covered witha layer of fine, clean bank gravel, which, after rolling, shall have a thickness of one-half inch. On this is spread a layer of fine granite screenings one inch thick, and the surface is again rolled. Each layer is flooded with water before rolling.

Fig. 70 shows a form of construction that is very common at the present time. It consists of a Telford foundation eight inches thick covered with a four inch layer of broken stone, a layer of screenings being added as a binding material. Many of the park roads in and about Boston are built in this way.

The method of construction used in Chicago at the present time is shown in Fig. 71. The specifications for this

are as follows,-

Grading.---Before paving, the street shall be graded to conform to stakes or profiles, to be given by the Engineer in charge, and thoroughly flooded, rammed and rolled, to give it a solid bed.

Macadam.---On the roadbed thus formed and completed will be spread a layer of clean, broken stone, entirely free from dust and dirt, not less than seven (7'') inches in depth in the center, and not less than five (5'') inches at the sides after being thoroughly rolled.

The stones shall be practically uniform in quality, and as near an approach to a cube in form as possible, and broken so as to pass through a ring not greater than four (4'') inches, and not less than two and one-half (2 1/2'') inches in diameter, and all stones that are wedge shape and do not approach uniformity of measurement on their sides, shall be taken from the roadbed, and no stones will be allowed to remain which are not sound, strong and equable in size and quality of material. On the above layer will be spread lime stone screenings, or bank gravel, as designat-

ed by the Commissioner of Public Works, in sufficient quantity to fill up all interstices, and then flooded and rolled with a fifteen (15) ton roller until the roadway is firmly compacted and solid and given a thoroughly even surface.

The above to be covered with a layer of medium lime stone broken so as to pass through a ring two (2'') inches in diameter entirely free from dust or dirt, and uniform in size and quality. The interstices to be filled with lime stone screenings, or bank gravel, and flooded. This layer shall not be less than two (2'') inches in depth at the sides, and not less than four (4'') inches at the center, after being thoroughly rolled.

The above to be covered with a topping of crushed granite, cube shaped as near as possible, and broken so as to pass through a two (2'') inch ring, which shall not be less than four (4'') inches in depth at the center, and not less than two (2'') inches on the sides, after thorough rolling. The interstices to be filled with best quality of fine or screened bank gravel, or lime stone

screenings, and rolled with a fifteen (15) ton roller, with occasional flooding of the pavement, until the street is firmly compacted and solid. This layer shall then be covered with granite screenings to a uniform depth of one-half (1/2") inch, and rolled and sprinkled until the same is firm and unyielding. In all the above, the depressions must be filled as the rolling progresses.

A more common way of constructing a road of this kind would be as shown in Fig. 72, each layer being rolled but no screenings used except on the top layer.

Fig. 73 shows a construction that has been used quite extensively in the last few years. Several miles have been laid in Bridgeport, Conn. and with very satisfactory results. The soil is brought to the required grade and is then rolled with a fifteen ton roller. The stone used is trap, broken into two inch pieces A four inch layer is spread on the prepared soil and rolled, screenings being added as a binding material.

With hard and tough material, a good dry soil, and light traffic, the four

inch construction, as used in Bridgeport may suffice; but for a heavy traffic over wet ground, the Telford sub-pavement with a layer of broken stone above it from 4 to 8 inches thick, is preferred by most engineers. A layer of sand is sometimes spread upon the prepared roadbed before the stone is put on to keep the mud from working up between the stones. This is advisable in wet ground, whether the Telford pavement is used or not.

(7) Maintenance and Repair of Broken Stone Roads.

The proper maintenance of a road consists in keeping its surface smooth and hard, removing the material worn out and replacing it by new material, and keeping open the side ditches, culverts and drains. A broken stone road requires constant attention to keep it smooth and hard. When a rut appears it should be at once filled with stones or it will increase in size very rapidly.

The general practice in European countries is to put a laborer in charge of a certain length of road upon which he is continually employed opening ditches,

removing the mud, and applying fresh road metal. The length of road which should be given to one man varies with the traffic, being sometimes much less than a mile and sometimes five miles or more. At certain seasons of the year when extensive repairs are required, he is assisted by other laborers.

In France, where there probably exists the most perfect system of road maintenance in the world, two methods are used.

Upon roads of moderate traffic, where the average daily tonnage does not exceed about 30 tons per foot of width, the road covering is kept at the original thickness by constant additions. As soon as a depression appears it is filled with a thin layer of stone, which, in a few days, becomes as smooth as the rest of the road. Except in wet weather it is usual to loosen the surface of the depression with a pick, before applying the stones, to hasten the consolidation, and sometimes a small quantity of binding material is added. These patches should always be small, as otherwise the

traffic will avoid them. When there are several depressions near together, the worst places should be patched first and allowed to become smooth before patching the others.

The stones for repairing should be somewhat smaller than those ordinarily used in constructing a road. The largest should not be over one inch and a half in longest dimension. They are kept in stone depots at short intervals along the side of the road.

Experiments made upon the roads of France show that the wear of good road metal is about one cubic yard per mile per year for each ''collar'' passing over it per day. A ''collar'' is an animal drawing a load, four animals drawing empty vehicles being reckoned as one ''collar''. This will serve as a basis for estimating the amount that ought to be used on any given piece of road to keep it at the original thickness.

Upon roads of heavy traffic, where the average daily tonnage exceeds about 30 tons per foot of width, it is not attempted to continually replace the ma-

terial worn out, but only such repairs are made as are necessary to keep the surface in good condition. The covering is allowed to wear as thin as possible with safety, when a thick layer of broken stone is added, and rolled as in forming a new road. Before applying this layer the surface of the old road should be loosened so that the new material will bind with it . This is best done by steel points which are inserted in holes in the tires of the driving wheels of steam road rollers.

The dust and mud should not be allowed to remain on the surface of a macadamized road. Several methods of removing them are employed.

A long handled broom of twigs is sometimes used, the sweeper standing in the middle of the road and sweeping from side to side.

A hand sweeping machine consisting of a wide broom mounted on a wheel and having handles similar to a wheelbarrow, is also used.

Hand scrapers of wood or steel similar to a hoe are often employed for removing mud.

A hand scraping machine consists of several scrapers fastened abreast on a horizontal bar, which is mounted on two wheels. This is worked back and forth across the road, scraping at each trip a width of 4 feet.

Sweeping machines drawn by horses are used in cities. A very common kind consists of a cylindrical revolving brush mounted on wheels at an oblique angle with the axle. It sweeps a width of about 7 feet and leaves the dirt in a line at the side. Fig.74 shows the ''Barnard-Castle'' Wrought-iron Street Sweeper which sweeps a width of 7 feet 6 inches.

Scrapers drawn by horses are also used.

3. Gravel Roads.

When it is not desirable to go to the expense of making a broken stone road, a gravel covering is often used and makes an excellent surface for a country road or village street. For pleasure drives a gravel surface well maintained is not excelled.

The gravel for a road covering should not be composed of clean and water worn pebbles, as that found along the sea

shore and river banks, but should contain a certain amount of earthy matter to serve as a binding material. Bank gravel often contains too large a proportion of earthy matter which should be screened out for the top layer.

The ordinary gravel road, Fig.76 is from 8 to 12 inches thick and is usually constructed in layers of about 4 inches.

The bottom layer may be of unscreened bank gravel, laid on the surface of the roadbed, which has been previously rolled if not sufficiently solid. This layer is rolled until partially consolidated, and another layer is added and rolled. If required, a third layer may follow and be treated in the same manner

The gravel for the top layer should be screened. For this purpose two wire screens are commonly used one with wires 1/2 to 3/4 inch apart, and the other with wires 1 1/2 to 2 inches apart. The pebbles which will not pass through the coarse screen and the fine earthy matter which passes through the fine screen should be rejected. If the gravel used does not have an excessive amount of earthy material the use of the fine

screen may be dispensed with, as a certain amount of binding material is necessary.

The rolling should always begin at the sides, which should be made quite solid before the roller is moved to the central portion of the road, so as to prevent the gravel from working out toward the sides. If the gravel is dry it should be watered as the rolling proceeds.

Some of the finest gravel roads that have ever been constructed are those in Central Park, New York. These have a foundation of rubble stone, or the Telford sub-pavement.

The rubble stone foundation has a thickness of 11 inches and is composed of stones from 4 to 12 inches long. The gravel was unscreened and was put on in two layers making a total thickness of 5 to 6 inches. (Fig.77).

The Telford foundation was 7 to 8 inches thick and the gravel on this was 5 1/2 inches thick deposited in two layers, the top one of which was screened. (Fig.78) The bottom layer was rolled with a light horse roller and the top

layer with a horse roller five feet long weighing six and one half tons, being 217 lbs. per inch. This passed over every part of the surface from 80 to 100 times.

4. Corduroy Roads.

A corduroy road consists of logs cut in lengths of 10 to 15 feet and laid side by side upon the natural soil.

Sometimes a part of the logs are split to a triangular section and used to level up between the others as shown in Fig.79.

To make the surface as smooth as possible a layer of brushwood and a covering of earth are often added.

Over soft or swampy ground such roads are very useful as a temporary measure, and they have been quite extensively used in some of the timber regions of this country.

A description of a journey from Pittsburgh to Erie a part of which was over a corduroy road, has already been given in the words of David Stevenson on page 12.

5. Plank Roads.

Plank roads were quite extensively used in this country thirty or forty

years ago.

The usual method of construction was as shown in Fig.80. Two lines of stringers were bedded in the ground about five feet apart and across these planks were laid usually 8 feet long and 3 or 4 inches thick. The ends of the planks were not laid in line, but there was a break of a few inches at short intervals to allow vehicles to easily get upon the planks from the sides. There was always an earth road at one side of the plank road to allow wagons to turn out in passing.

When there was a large amount of traffic so that a greater width than 8 feet was needed it was found better to lay another track, rather than to make a double track 16 feet wide, as it was found that on the wide track the greater part of the traffic followed the center, thus causing unequal wear.

On new plank roads the tractive force is very small, but the planks wear rapidly and soon become warped and displaced.

In some of the cities near timber regions of the western part of the United

States, the entire surface of the street is covered with planks. The planks are usually 4 inches thick and extend in one piece from the gutter to the center of the street.

6. Charcoal Roads.

In some parts of Michigan and Wisconsin, roads have been made with a covering of charcoal. A description of the method of constructing them is given as follows:-

''Timber from six to eighteen inches through is cut twenty-four feet long, and piled up lengthwise in the center of the road, about five feet high, being nine feet wide at the bottom and two at the top, and then covered with straw and earth in the manner of coal-pits. The earth required to cover the pile, taken from either side, leaves two good-sized ditches and the timber, although not split, is easily charred; and, when charred, the earth is removed to the side of the ditches, the coal raked down, to a width of fifteen feet, leaving it two feet thick at the center and one at the sides, and the road is completed''.

This was found to make a very fair road, firm and dry and free from ruts.

It is evident that this manner of constructing a road would only be adopted in a new country, where the timber was of no market value.

7. Shell.

Along the South Atlantic and Gulf coasts, oyster shells are used quite extensively for forming the road surface. This form of covering is used not only for roads but also for streets in many of the cities. For light traffic it is found to give very satisfactory results, although wearing much faster than broken stone.

STREETS.

ARRANGEMENT.

In laying out the streets of a new city or village, the most natural arrangement is the rectangular. With this system the least possible area is used up in streets, and the remaining area is in the most convenient shape for building purposes. In such a system, however, a great amount of time is necessarily wasted in going from one point to another, as it is always necessary to travel the two sides of a right angled triangle of which the straight line between the points is the hypothenuse, unless the two points are on the same street. The extra distance which it is necessary to travel may vary from zero to .41 times the shortest distance between the points. Many of the cities in this country are laid out on the rectangular system, Philadelphia and Chicago being good examples. Fig.81 shows a map of a portion of the latter city.

The advantages of such a system over the irregular arrangement shown in the map of Boston, Fig.82, are very apparent.

An improvement on the rectangular sys-

tem is made in the cities of Washington and Indianapolis, Figs.83 and 84, where diagonals are combined with the rectangular system. An extension of the Indianapolis system, as shown in Fig.85, would undoubtedly be an improvement.

In the western part of this country, where the land is cut up into sections, it is customary to have the streets run East and West, and North and South. In many places the ground is so nearly level that there is no disadvantage in this, but it would not be advisable to follow this method if the topography were such as to make other directions more favorable for the construction of a sewer system, or for the laying of the street grades. In fact, it is hot advisable to stick too closely to any regular system, when, by so doing, steep grades are made necessary. Sometimes when a new town is laid out along a railroad the streets are built parallel to, and at right angles to the railroad.

The most convenient sizes for blocks has been found to be about 300 feet square. In some places the section is divided into sixteen rows of blocks in

one direction, and eight or sixteen in the other, making the blocks, from center to center of street, 330 feet by 660 feet, or 330 feet by 330 feet. The latter is probably a better arrangement, as 660 feet is rather too long a distance between streets.

An alley should extend through the middle of a block in one direction to give access to the back of lots.

In Chicago the blocks are divided into lots 25 by 125 feet and this size has been found the most convenient in many places.

Fig.86 shows a block one eighth of a mile long and one sixteenth of a mile wide, divided into lots.

The lower part of Fig.87 shows the same method applied to a block one sixteenth of a mile square and the upper part shows a good method of subdividing a block with a diagonal street through it.

GRADE.

The grade of a street, unless it is so situated that it is necessary for many heavy loads to pass over it, may be somewhat steeper than that allowable on

an important road, for it is usually the case that any given point can be reached by a somewhat longer route on which the grades are easier than on the most direct route. Grades as steep or even steeper than 1 in 10 are not uncommon, but they should never be allowed except on unimportant streets, over which it is not necessary to haul heavy loads.

For purposes of drainage it is advisable for a street to have a minimum grade of about 1 in 200. A method sometimes adopted for giving proper drainage where the ground is level, is to give the gutters a slope, while the center of the street remains level. This necessitates a constantly changing transverse slope, varying from a minimum at the summits to a maximum at the outlets of the gutters. The curb stone in such a case may be set on a level grade, parallel to the center of the street, or may follow the grade of the gutter at a uniform height above it. The former method is preferable, as it gives a better appearance to the street.

CROSS-SECTION.

A street, as usually constructed, in-

cludes a carriage way in the center, and a footpath or sidewalk on each side. For a business street, this is all that is required.

For residence streets or pleasure drives, it is very common to have grass plate with trees growing upon them, between the sidewalk and carriage way, and sometimes two carriage ways are built with a strip of grass ground between them.

Alleys very rarely need to be provided with footpaths. If for any reason one is needed, a narrow one on one side will be sufficient.

The width of a street should seldom be less than 50 feet. For principal business streets a width of 100 feet or more may often be required. A very common width in the west is 4 rods or 66 feet. Alleys should never be less than 14 feet wide. To prevent the surface of a street from being continually torn up it has been proposed that sewers, water pipes etc. be laid in the alleys, in which case a width of 20 feet would not be too great. For most important residence streets or boulevards, in which a

wide strip of the street is used for a park, as great a width as 200 feet is sometimes allowed.

The roadway should have a slope from the center each way, which may vary from 1 in 20 for earth streets to 1 in 50 for smooth impervious surfaces like asphalt. A slope of 1 in 40 is very common with block pavements. With a steep longitudinal grade it is customary to increase the transverse slope.

The transverse slope in an alley is usually from the sides downward toward the center, making a single gutter along the middle.

The width necessary for a sidewalk will of course depend upon the traffic passing over it. A width of 2 or 3 feet will usually suffice for a footpath in an alley, if any is needed, while for a wide business street two walks, each 15 feet wide or even more may be required. For the ordinary street the width of each sidewalk varies from 1/4 to 1/2 that of the roadway.

The sidewalk should have a fall from the street line toward the gutter, varying from 1 inch in 2 feet to 1 inch in

5 feet, according to the material of which it is composed.

The footpath should be separated from the roadway by a curb, the top of which is usually from 6 to 10 inches above the gutters. In some of the cities of the Northwest, where there is a great amount of snow, the top of the curb is sometimes as much as 18 inches above the gutter, so that the accumulation of snow in the roadway will not be higher than the sidewalks.

Where the cellars of buildings extend under the sidewalks, as is very common in some cities, a retaining wall called a curb wall is built to hold back the earth under the roadway. On the top of this the curb is set.

When the ground is of such a nature as to require subdrains, a longitudinal tile drain is often laid on each side of a road, under the curb.

Figs. 88,89 and 90 show cross-sections of some typical streets and roads both in this and foreign countries.

SURFACE OF ROADWAY.

The surface of a street may be constructed of any of the following materi-

als:-

1. Earth.
2. Broken Stone.
3. Gravel.
4. Plank.
5. Shell.
6. Cobblestone.
7. Rubblestone.
8. Stone Block.
9. Wood Block.
10. Brick.
11. Asphalt.
12. Coal Tar.

Of these, the first five have been discussed under roads, leaving the pavements to be considered.

Before considering the different kinds of pavements, let us get a clear idea of the requisites of a good pavement.

1st. A pavement should be smooth and hard so as to cause as little resistance to traction as possible.

2nd. It should be so constructed as to give a good foothold for horses, and not become slippery under traffic.

3rd. It should not be of such a material as will produce dust and mud.

4th. It should be impervious to liq-

uids so that it can be easily cleaned, and will not absorb filth.

5th. It should be noiseless under traffic.

6th. It should be so constructed as to be easily taken up and firmly relaid in small patches, so as to give access to gas and water pipes.

7th. It should be economical in first cost and maintenance.

It is very evident that no pavement has yet been invented that will answer all these requirements.

Earth, broken stone, gravel and shell coverings give a good foothold, are practically noiseless, and are economical in first cost, but are lacking to a greater or less degree in all the other requisit es of a good street covering.

Plank, when new, possesses most of the requisit es of a good pavement, but it wears very rapidly under heavy traffic, is expensive to maintain and when old absorbs and retains filth.

6. Cobble Stone Pavement.

Very little cobble stone pavement is laid at the present time, although there are many hundred miles of it in exist-

ence in the cities of the United States

The best cobble stone pavement, Fig.91. is formed of egg shaped pebbles, from 6 to 10 inches long, 4 to 8 inches wide and 3 to 6 inches thick, set with their larger end up, in a bed of sand or gravel usually from 8 to 10 inches in depth. The sand should be moistened and rolled or rammed so as to be fairly compact. To allow this it must not be perfectly clean but must contain a small amount of earthy matter. The stones, after being set, are rammed with a heavy rammer to a firm bed, care being taken that their tops are at the proper grade. A layer of sand or gravel is then spread over the surface and left to be worked into the joints by the traffic.

In some cities a very inferior cobble stone pavement has been laid, Fig.92. the stones being of very irregular sizes so that the exposed surfaces vary from 3 to 12 or 14 inches in greatest dimension.

A cobble stone pavement possesses few of the requisit es of a good pavement. It gives a good foothold for horses when formed of small sized stones, and is

very cheap in first cost. It is very rough for traction, it is difficult to clean, the large joints being receptacles for mud, dust and filth, is extremely noisy, and is not easily relaid in good shape when taken up for repairs to pipes. As the stones are smooth, and touch each other only over a small area, they settle out of place under heavy loads, and ruts soon appear, which make it very expensive to maintain such a pavement in its original condition.

On account of the good foothold given by a cobble stone pavement formed of small stones, it is often used between the rails of horse car tracks.

7. Rubble Stone Pavement.

Rubble stone pavement is formed of irregular shaped stones, from 5 to 6 inches deep, 3 to 6 inches wide, and 6 to 12 inches long.

They are laid on a bed of sand or gravel in the same manner as cobble stones, with their broadest edge up, so as to form a close pavement. Continuous joints in the direction of the traffic should be avoided as they would develop into ruts. After laying, the stones

should be rammed to an even surface and a firm bearing, and a layer of sand or gravel spread over the surface.

The rubble stone pavement is superior to cobble stone, as it has a smoother surface and, as the sides of the stones are rough and have a larger area of contact with each other, it retains this surface better. As to the other qualities of a good pavement, it is little better than cobble stone.

8. Stone Block Pavement.

A pavement formed of stone blocks, with rectangular faces, is far superior to either the cobble or rubble stone pavement.

The foundation of a stone block pavement, as most commonly laid, consists of a layer of sand or gravel, varying in thickness from 6 to 12 inches. This should be consolidated by ramming or rolling. An old cobble or rubble stone pavement, or a macadamized road makes a good foundation for a stone block pavement. A foundation of broken stone, prepared and rolled as for a macadamized road, and having a thickness of 6 to 8 inches, is often used. A pavement of

rough stones like the Telford foundation is often used.

The best form of foundation consists of a layer of cement concrete having a thickness of 5 to 10 inches. The concrete is made of cement, clean, sharp sand and broken stone usually not over 2 1/2 inches in greatest dimension. The proportions of the cement, sand and stone, vary somewhat in different cities but the following are quite common,- 1 part of American cement, 2 parts of sand, and 5 to 6 parts of broken stone. If Portland cement is used, the proportions of sand and broken stone may be increased slightly. The sand and stone should be free from dirt or earthy matter. Screened gravel pebbles are sometimes used instead of the broken stone.

The common way of making the concrete is to first mix the cement and sand dry, then add enough water to make a stiff mortar. The stone, having been wet, is then thoroughly mixed with the mortar. The concrete is then laid in place and compacted by ramming.

In Liverpool the concrete foundation is made of 1 part of Portland cement,

5 to 6 parts gravel, and 7 to 8 parts broken stone. The cement and gravel are mixed dry and enough water is added to make the mixture retain its form when pressed in the hand. A layer of broken stone is then spread upon the roadbed, which has been previously compacted. This is thoroughly wet and a layer of the mortar is spread over it, and then another layer of stone. The stone is then beaten with a flat sheet iron beater resembling a spade. Another layer of mortar and a layer of stone are added and beaten as before, and this process is repeated until the required thickness is attained.

Foundations of bituminous concrete have also been used. This is made as follows.- The required thickness of broken stone is spread over the prepared roadbed and rolled. Over it is then poured hot coal tar or a mixture of coal tar and creosote oil which fills the crevices between the stones. On this is spread a thin layer of small broken stone and the rolling repeated.

Whatever the character of the foundation, a thin layer of sand or fine grav-

el should be spread upon it to make a bed for the paving blocks.

The first thing to be considered with reference to the block, is the kind of stone which shall be used. This will have to be decided to some extent by the locality, it sometimes being necessary to use an inferior material on account of the cost of bringing a better material from a distance.

A good paving stone should be hard and tough and should not become slippery with wear. A stone that will split with a smooth fracture is preferable to one that will not, as less work will be required to bring the faces to the desired smoothness.

Nearly all the granites make good paving blocks, the syenites being especially fitted for this purpose. Some of them are, however, inclined to become slippery with wear. The trap rocks are also used and with satisfactory results. The sand stones are, as a general thing, too soft. The Medina sandstone, however is used to quite an extent in some parts of the West, and although not as hard as granite it has the advantage of not

becoming slippery with wear. Most of the lime stones are too soft, wear very rapidly and fall to pieces in a short time. Yet some of the harder varieties are used and make a fairly good pavement. They do not become slippery.

The size of the blocks we will next consider. The original Belgian blocks, as they were called (Fig.93a.), were usually cubical or nearly so, sometimes as large as 8 inches in each dimension. A very common size was 5 to 7 inches long, 5 to 6 inches wide, and 5 to 7 inches deep. At one time blocks were used in New York 10 to 18 inches long.5 to 12 inches wide, and 10 inches deep. Such large blocks do not give a good foothold as the joints are so far apart. Present practice in this country favors a block 6 to 12 inches long, 3 to 4 1/2 inches wide, and 6 to 8 inches deep. A block wider than this does not give a good foothold. The objection to very short blocks is that there is a tendency for ruts to form, when there are so many joints in the line of the traffic, unless great care is taken that joints are properly broken. On the other hand, the

objection to long blocks is that the joints are so far apart that horses are likely to slip sideways. In Liverpool, blocks 3 1/4 by 3 1/4 by 6 1/4 inches deep are used in some cases and 4 inch cubes in others. There, however, great care is taken to have the blocks of a uniform size and the faces smooth, a maximum variation of but a quarter of an inch being allowed. It is thus possible to break joints perfectly.

Methods of laying blocks. The blocks are laid close together usually with continuous joints across the street. (Fig.94) Where stones of different widths are allowed it is necessary to have those in the same course of the same width, in order to keep close, straight joints.

Sometimes the blocks are laid with the continuous course at an angle of 45 to 60 degrees with the line of the street. (Fig.95) This arrangement is a little better than the former for traction, as wheels cross the joints diagonally and do not strike the edges of the blocks with as much force as when crossing at right angles. For the same reason the

wear of the blocks is less. The foothold, however, is not as good as when the joints are at right angles to the line of traffic.

A modification of the second method which has been used on steep grades, consists of two sets of diagonal courses each making an angle of 45 degrees with the line of the street, and meeting in the middle of the street, with their angle pointing up the ascent (Fig. 96) With this arrangement, each continuous joint serves as a channel to conduct the surface water to the gutter.

At the intersection of two streets it is customary to arrange the blocks as shown in Fig. 97, to avoid continuous joints along the line of traffic.

After the blocks are laid, the joints are usually filled with sand, and the blocks are thoroughly rammed three or four times with a heavy rammer weighing 60 to 80 pounds. Sometimes the joints are filled with clean gravel and a cement grout is poured in, filling all the spaces not occupied by the gravel. A still better filling, which has been used to quite an extent of late years in

connection with the gravel, consists of a mixture of coal tar pitch and creosote oil, in the proportion of about fifty gallons of oil to one ton of pitch. The joints are first filled with the gravel and the blocks thoroughly rammed; then the coal tar mixture is poured into them while hot.

A well constructed stone block pavement possesses most of the requisites of a good pavement. It offers little resistance to traction, gives a good foothold, is easily cleaned, is impervious to liquids when laid with coal tar joints, when on a concrete foundation is relaid as good as new if taken up in small patches, although difficult to take up. It is very noisy, is very expensive in construction, but costs very little for maintenance.

Below are given specifications and descriptions of stone block pavements as laid in various cities.

Extracts from specifications for granite block pavement as laid in Providence R. I.(Fig.98).

Quality and Dimensions of Stone Blocks.

The stone blocks for the pavement are to be of granite of a durable, sound and uniform quality, not liable to wear slippery, each measuring on the face or upper surface not less than eight or more than ten inches in length,(the whole to average not more than nine inches), not less than three nor more than four inches in width, not less than seven nor more than eight inches in depth, to be split and dressed so as to form, when laid, end and side joints not exceeding one inch wide, top or bottom, with fair and true surfaces on top and bottom. They will be carefully inspected after they are brought on the line of the work, and all blocks which in quality or dimensions do not conform strictly to these specifications will be rejected and must be immediately removed from the line of the work.

Removal of Present Pavement and Preparation of Road-bed.

The present pavement, including all cross-walk stone rejected by said Engineer as unfit for further use, shall be taken up and delivered at the City Yard (so called) satisfactory to the City En-

gineer.

The sub-soil or other matter shall then be excavated to such a depth as that when the surface has been thoroughly compacted by ramming or rolling (as shall be done), it shall be left fourteen and one-half inches below the grade of the top line of finished pavement, except the cross-walks at intersecting streets, where the excavation after ramming, etc., shall be thirteen inches below the top line of walk. Should there be any material of such a nature that it cannot be compacted satisfactory to the Engineer, such material shall be removed to a depth of not less than two feet, and the space filled with gravel or sand, thoroughly rammed.

All holes and inequalities shall be likewise filled.

No ploughing will be allowed in preparing the foundation.

Concrete Foundation.

Upon the foundation thus prepared, except under the cross-walks at intersecting streets, shall be placed a bed of concrete five inches in depth.

Sand Bed.

On this concrete foundation shall be laid a bed of clean, sharp sand, perfectly free from moisture (made so by artificial heat if deemed necessary by the Engineer), not less than one and one-half inches thick, to the depth necessary to bring the pavement to the proper grade when thoroughly rammed.

Laying the Blocks and Filling of Joints.

Upon this bed of sand the granite blocks will be laid. The blocks will be laid at right angles to the line of the street and intersecting streets. They will be placed as close as possible to one another, forming joints not more than one inch in width, top and bottom; each course to be formed of blocks of uniform width and depth, and so laid that all longitudinal joints shall be broken by a lap of at least two inches. When thus laid the blocks shall be immediately covered with clean, hard, dry gravel, artificially dried if deemed necessary by the Engineer. This gravel shall be free from sand, it shall be such as has passed through a sieve of three-quarters of an inch mesh and re-

tained by a quarter inch mesh. It shall be brushed into the joints. The blocks are then to be carefully rammed. More gravel shall then be brushed in to fill the joints, the blocks again carefully rammed; the process to be repeated until the joints are full, and the blocks brought to an unyielding bearing, with uniform surface, true to the crown of the roadway as given by the Engineer.

There will then be poured into the joints, in a boiling state, an asphaltum mixture, composed of coal-tar pitch and creosote oil, in the proportions of fifty gallons of oil to one ton of pitch; these are to be melted together in iron boilers holding not less than twenty-five hundred pounds. It will be poured into the joints of the pavement until the sand beneath and the gravel between the blocks will absorb no more and the joints are filled flush with the upper surface of the pavement.

Material to be kept dry.

The stone for the pavement, the sand for the bed, and the gravel for the joints shall each and severally be laid only when dry and free from moisture.

After being laid, the contractor shall protect them from the weather until the joints have been filled with said asphaltum mixture, and should they become moist from any cause before filling the joints with said mixture, the contractor shall at his own expense remove that portion of the work so moistened and replace and complete the same with dry materials.

The contractor shall in each and every case so protect the work when unfinished as to prevent water from entering between the stone blocks and the concrete foundation.

The blocks to be laid next to the railroad stringers shall be selected as free from bunches as possible, and laid as close against the timber as can be done.

The contractor will, at his own expense, dress or trim off all bunches from the curb-stone which may in any way prevent the proper laying of the stone blocks or forming the joint of the same.

Concrete.

The concrete shall be composed of one part of fresh ground American hydraulic

cement, of the best quality, two parts of clean, sharp sand, and six parts of broken or screened stone.

All cement furnished by the contractor will be subject to inspection and test before it is used, and shall when mixed be capable of resisting a tensile strain of fifty pounds per square inch, after thirty minutes exposure in air and twenty-four hours immersion in water.

The contractor will be required to furnish the Engineer or Inspector full facilities for examining and testing all cement to be used, and the Engineer is to decide upon the charcater and severity of the test to be applied; and all cement, which in his opinion is of improper or inferior quality, must be immediately removed from the work. When cement is accepted, if not immediately used, it must be protected from the weather and kept dry, and in no case will it be allowed to be placed upon the ground without blocking under the barrels.

The broken or screened stone to be sound and solid, free from dust and dirt and of a size not larger in any dimen-

sion than will pass through a two-inch ring.

The cement and sand is to be made into mortar in boxes if required, and the broken or screened stone, which shall be sprinkled so as to wet the surface of the stone, shall then be added and the whole shall then be quickly and thoroughly mixed until every stone is coated with mortar.

The concrete thus made shall then be placed in proper position and there rammed until it is thoroughly compacted and has a clear mortar surface, which surface, when left, shall be nine and one-half inches below the grade of the top of the finished pavement.

The surface shall be kept wet, if required, until covered with sand. At least thirty-six hours shall be allowed for the concrete to set before the pavement is laid When connection is to be made with any layer, set or partially set, the edge of such layer must be broken down and shall be free from dirt and properly wet so as to make the joint fresh and close

No driving on the concrete bed will be

allowed. The sand is to be placed on the concrete from wheel-barrows.

No allowance in measurement will be made for any concrete which may be driven into the earth by ramming below the grades given for the sub-foundation.

Specifications for granite block pavement as laid in Chicago, Ill. (Fig.99).

Grading. Before paving, the street shall be graded to conform to stakes or profiles, to be given by the Engineer in charge and thoroughly flooded, rammed and rolled to give it a solid bed.

Foundation For Stone Pavement. Upon the bed thus formed and compacted shall be spread a layer of clean, broken limestone, entirely free from dust, dirt or other foreign substance, not less than six (6'') inches in depth, after being thoroughly rolled. Said stone shall be practically uniform in quality, of angular fragments, having rough faces obtained by fracture, and measuring not more than two and one-half (2 1/2) inches in their largest dimensions, nor less than one (1) inch, in about equal proportions. Upon this a bed of limestone

screenings, or of fine, clean bank gravel, containing no pebbles of larger dimensions than one and one-half (1 1/2) inches, shall be spread in such quantity that when thoroughly flooded it shall completely fill the interstices of the stone and leave besides one (1) inch in depth over the whole surface of the stone, after rolling.

The stone and gravel shall be flooded with water, and thoroughly rolled with a steam roller, weighing not less than fifteen (15) tons, until the entire mass is brought to a true and uniform surface and thoroughly compacted, to the satisfaction of the Commissioner of Public Works or his representative. Stone and gravel together to have a thickness of not less than seven (7) inches after having been thoroughly rolled, and the surface thereof to be from eight to nine (8-9) inches below the top of the finished pavement. Over this shall be evenly spread a bed of clean, fine, sharp sand, thoroughly dry, not less than two (2) inches nor more than three (3) inches in thickness, to serve as a bed for the granite blocks, which shall

be laid directly upon and imbeded in it.

Granite Blocks. The pavement to consist of syenite or granite blocks or stone, equal in quality to standard samples in the office of the Commissioner of Public Works, of a uniform grain and texture, without lamination or stratification, and free from excess of mica or feldspar.

It is expressly understood that granite, wearing roughly, and therefore affording better foothold for horses, will be considered preferable to the hardest. Hard basaltic stone, which will take a smooth polish under traffic, shall not be used. Soft or weatherworn stones, obtained from the surface of the quarry, will not be accepted. The stone blocks must be so quarried or dressed as to present substantially rectangular faces, with practically straight edges on top, bottom and sides, and all blocks whose faces vary more than half (1/2) an inch from a rectangular shape will be rejected. The sides and ends of the blocks must also be so quarried or dressed that they will make close-fitting joints. Blocks having projections or knobs larg-

er than half (1/2) an inch will be rejected, unless so dressed that said projections or knobs will be within the limits prescribed. The dimensions of the stone will be from three and one-half to four (3 1/2 - 4) inches wide, six to seven (6 - 7) inches deep, and not less than six (6) nor more than ten (10) inches long. Each stone shall have even top and bottom beds.

The blocks will be carefully inspected after they are brought on the line of the work, and all blocks or other material, which in quality or dimensions do not strictly conform to these specifications, or which may be otherwise defective, shall be rejected, and must be immediately removed from the line of the work by the contractor. The contractor will be required to furnish such laborers as may be necessary to aid the inspector in the examination and culling of the stone and other material, and in case the contractor shall neglect so to do, such laborers as in the opinion of the Commissioner of Public Works may be necessary, will be employed, and the expense incurred shall be deducted from any mon-

ey then due, or which may thereafter become due to the contractor.

The blocks must be laid in uniform courses across the street, and spaces between the sides or ends of the blocks, when in place, shall in no case be less than one-quarter (1/4) of an inch nor exceed five-eighths (5/8) of an inch. The stone blocks shall be so laid as to break joints in alternate courses, each course, as far as practicable, to be of uniform depth and width, and so laid that all longitudinal joints shall be broken by a lap of at least two and one-half (2 1/2) inches.

When thus laid the pavement shall immediately be covered with clean,screened, dry (roofing) gravel, free from sand or loam, or pebbles smaller than one-sixteenth (1-16) of an inch, or larger than one-half (1/2) an inch in size, in proper quantities, and raked until all the joints become filled therewith, and the blocks then rammed with a seventy-five (75) pound rammer, the point of which shall be three and one-half (3 1/2) inches in diameter, by competent and experienced workmen, to a firm, unyielding

bed, and uniform surface to proper grade. In the above described ramming each stone should be struck two full blows; a light rammer shall then be used to bring the pavement to a perfectly uniform surface.

Aspace of three-fourths (3/4) of an inch shall be left between the top of the gravel in the interstices and the top of the pavement, which will be filled full with a hot asphaltic mixture This mixture must be poured into the joints of the blocks at a temperature of 300 degrees Fahrenheit until the sand beneath and the gravel between them will absorb no more, and the joints are filled flush with the upper surface of the pavement. In no case shall be used for this purpose less than two and one-half (2 1/2) gallons per square yard of paving.

Said asphaltic mixture shall be composed of coal tar, pitch made from coal tar, gas tar and creosote oil, in the proportion of one (1) cwt. of pitch to four (4) gallons of tar and one (1)gallon of creosote, proportions which are varied somewhat, according to the quali-

ty of the pitch used. The materials composing the mixture must be melted together and boiled for from one (1) to two (2) hours in a boiler adapted to the purpose, and must be tempered to the satisfaction of the engineer in charge before it is poured into the joints; and any of the cement which does not flow freely at the proper temperature shall be rejected and removed from the work.

Another paving cement may be obtained from direct distillation of coal tar, and of the consistency ordinarily numbered between five (5) and six (6) at the manufactory.

The Commissioner of Public Works reserves the right to decide which of the two named compositions shall be used.

The object of asphaltic jointing is to make the paving impervious to moisture; to create a bond with a degree of elasticity sufficient to prevent it from cracking and to prevent formation of mud thereby facilitating the cleaning of the pavement.

It is therefore expressly understood, that the Commissioner of Public Works will permit only the very best asphaltic

mixture known to be used for the above purpose.

After the aforesaid treatment the entire surface of the street shall be covered with a light coating of dry fine gravel, containing no pebbles larger than three-quarters (3/4) of an inch, for the purpose of consolidating the same with the asphaltic jointing.

Extracts from Specifications for Dressed Block Medina Sand-stone Pavement as laid in Buffalo, N.Y.

Grading.--- The street to be graded to such grades, sub-grades and cross-sections as the Engineer shall direct; the sub-grade of the roadway to conform to the proper crown of the pavement. All surplus material to belong to, and must be disposed of , by the contractor; any deficiency of earth to be supplied by him. Soft or spongy places, not affording a firm foundation, will be dug out and refilled with good earth, well rammed, and the entire roadbed will be thoroughly rolled with a steam roller weighing not less than five tons.

Foundation.--- Upon the roadbed thus

prepared will be laid a bed of hydraulic cement concrete, six inches in thickness, to be made as follows:

One measure of Buffalo, or equally as good cement, equal to the best quality of freshly-burned Rosendale cement, and two of clean, sharp sand will be thoroughly mixed dry, and then made into a mortar, with the least possible amount of water; broken stone, thoroughly cleaned from dirt, drenched with water, but containing no loose water in the heap, will then be incorporated immediately with the mortar in such quantities as will give a surplus of mortar when rammed. This proportion, when ascertained, will be regulated by measure. Each batch of concrete will be thoroughly mixed. It will then be spread, and at once thoroughly compacted by ramming until free mortar appears upon the surface. The whole operation of mixing and laying each batch will be performed as expeditiously as possible. The upper surface will be made exactly parallel with the surface of the pavement to be laid.

Upon this concrete base will be placed

a layer of sand three inches in depth and of a quality to be approved by the Engineer, as a cushion upon which will be placed the paving blocks.

The space between the curbs must be paved with the best quality of dressed block Medina sand-stone, to be approved by the Engineer, and the blocks shall be not less than three (3) nor more than four and one-half (4 1/2) inches thick, and not less than six (6) nor more than seven (7) inches deep, and from seven (7) to twelve (12) inches long. The surface of the stones to have parallel sides and ends with right-angle joints, and so prepared that when in place and resting against the adjoining block the joints, in their widest parts, shall not exceed one-half (1/2) inch in width for a distance of at least three and one-half (3 1/2) inches from the top down, and set tight together at side and end joints; stones are to be split or broken with the top surface hammer cut or ''axed'' off when necessary to render them smooth; sides and ends to receive similar treatment when necessary to secure the half (1/2) inch joints as spec-

ified; blocks are to be set tight together in uniform rows, breaking joints at least two (2) inches and resting against blocks in the same and adjoining course ;those of uniform thickness to be placed together in the same row, set upon three (3) inches of sand;blocks of the least depth allowed, not to be ''bolstered up'', no gravel or sand to be placed on top as blocks are laid. Blocks to be set perpendicular to the grade, and in right angle courses across the street, except at street intersections, where the courses are to be set at such angle as the Engineer shall direct. The pavement shall be subject to the following treatment by the contractor, and in such order and to such extent as the Engineer shall direct.

Ramming.--- The paving to be rammed as may be directed, with a paver's rammer, weighing not less than ninety pounds. No iron of any kind being allowed on its lower face to come in contact with the paving. The pavement to be surfaced up by using a long straight-edge, and when complete to conform to the true grade and crown of the roadway, as directed by

the Engineer.

Concrete Filling.--- The joints or spaces between the blocks not less than five inches in depth, to be filled with a concrete composition composed of not less than ten (10) per cent. of refined Trinidad Asphalt, mixed with coal tar cement distilled at a temperature of not less than 600 degrees, Fah.,and the whole mixed with such proportion of still-wax as not to soften or become brittle under heat or cold. The composition shall be heated and used at a temperature of not less than 300 degrees Fah.,to be determined by a proper guage or indicator placed upon the tank used in the street; extra material and care shall be used at the gutters in filling all joints, in both paving, curbing and around catch-basins, or other receptacles, to effectually prevent the leakage of water into the sub-roadway; all joints to be completely filled to the top before adding top-dressing.

The concrete not to be used until the blocks are completely dry.

Top-dressing.--- The surface of the paving, when completed as above, shall

be covered with a half inch top-dressing of clean, coarse sand or gravel of approved quality.

Stone Block Pavements in Liverpool, Eng

First Class Streets. (Fig. 100)

The foundation consists of a layer of Portland cement concrete six inches thick. This is allowed to set for ten days before paving is begun upon it.

On this foundation is spread a layer of fine gravel not over one half inch in thickness.

The paving blocks or ''sets'' are of granite and are 3 1/4 by 3 1/4 by 6 1/4 inches deep. These are laid as close together as possible, and the joints are then filled with clean gravel. The stones are then rammed and more gravel added, the operation being repeated as long as the gravel settles. A hot mixture of coal tar pitch and creosote oil is then poured into the joints, and the entire surface is covered with one-half inch of gravel.

Second Class Streets.

The foundation consists of a six inch layer of cement concrete, or sometimes

bituminous concrete.

The paving blocks are of granite, either 4 inch cubes, or 3 inches wide, 5 to 7 inches long, and 5 to 6 1/4 inches deep.

Third Class Streets.(Fig.101)

The foundation consists of a 10 inch pavement of rough stones set on edge, covered with a layer of gravel.

The paving blocks are 4 inch cubes of granite.

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9. Wood Block Pavements.

Pavements formed of blocks of wood have been used in Russia for hundreds of years. The first wood pavement was laid in London in 1839. In the United States the first wood pavements were laid in New York and Philadelphia about 1835.

Any of the forms of foundation used for a stone block pavement may be used for a wood block pavement. Another form, which is the most common one in this country, consists of one or two layers of boards upon a bed of sand, the blocks resting directly upon the boards.

Blocks of various shapes have been used. The first pavements laid in this

country and in England were formed of hexagonal blocks, laid with the fibres of the wood upright. Those laid in New York were 6 inches across and 8 inches deep. This form was known in England as the Stead pavement, from the name of the first constructor of wood pavements in that country. The edges of the block were usually champfered to give a foot-hold for horses.(Fig.102)

One of the earliest forms used in New York consisted of blocks 6 inches square and 12 inches deep.

An old form of pavement, known as Carey's, that was used to some extent in England, was composed of blocks of wood 6 or 7 inches wide, 12 to 14 inches long and 8 inches deep. The sides and ends of the blocks were alternately concave and convex to give support to each other A later form of this pavement had only the ends of the blocks concave and convex, and the size was decreased to 4 inches wide, 9 inches long, and 6 inches deep.(Fig.103)

Another wood pavement that was used to some extent in England was that known as Clark's. The shape and method of manu-

facturing the blocks, which were especially designed to give a good foothold, is shown in Fig.104.

De Lisle's wood pavement consisted of blocks whose top and bottom surfaces were cut diagonally to the direction of the grain. Holes were made in the side of each block to receive dowels used for the purpose of holding the blocks in place.

Wood paving blocks, as now laid, are usually from 6 to 12 inches long, 3 to 4 inches wide, and 6 inches deep.

In the western part of the United States, a wood pavement, composed of round cedar blocks from 4 to 8 inches in diameter, and about 6 inches deep, is extensively used. These blocks are, for the most part, simply sections of the trunk of the tree with the bark removed.

Various kinds of wood are used for paving blocks. In England, the Swedish yellow deal and the pitch pine are considered as among the best materials. In the United States, besides cedar, white pine has been used to some extent.

To prevent premature decay the blocks are sometimes treated by one of the wood

preserving processes. This has been done in London, where the creosoting process has been used. It is claimed by some that the blocks wear less rapidly when so treated, but it is questionable whether the advantage gained is sufficient to pay for the extra expense incurred. Where such processes are used, the blocks should be inspected before being treated, as it is impossible to do so satisfactorily afterwards. In this country, the blocks are usually laid in their natural state.

The removal of the sap wood, which is the first to decay, will lengthen the life of a paving block. In some of the western cities of the United States, cedar blocks, from which the outer or sap wood ring has been removed, are being used. The pavements laid with these blocks are said to remain in good condition much longer than those laid with blocks from which the bark only has been removed.

The pavement of round blocks is laid as is shown in Fig.~~105~~. 109

The rectangular blocks are laid in continuous courses running across the

street, or sometimes diagonally, as with the stone block pavement. At street intersections the arrangement shown in Fig.97 should be used.

The blocks are laid with close longitudinal joints, and a spaceshould be left next the curbing to allow for the expansion of the wood. This should be an inch or two wide according to the widthof the street, and should be filled with sand.

The transverse joints are usually left open from one-half to one inch. Sometimes a batten is placed between the rows to keep them the necessary distance apart. In London, iron studs are sometimes driven into the sides of the blocks and allowed to project a short distance, thus keeping the joint the required width.(Fig.105)

The joints may be filled with sand, cement grouting, or gravel and coal tar composition.

The surface should always be covered withalayer of sand or gravel which is rolled into the fibres of the block by the traffic.

The life of a wood pavement will vary

with the character of the foundation, kind of wood used, and the class of traffic which passes over it. In the western cities of the United States, the cedar block pavement has an average life of six to eight years, but under heavy traffic becomes very rough after two or three years.

In London wood pavements have been used on streets with a traffic of 400 tons per day per foot of width, 50% greater than that on Broadway, New York, and about 100% greater than that on Devonshire Street, Boston,and have lasted from six to eight years. The depth of the annual wear of the blocks varied on different pavements from .19 to .46 of an inch. Although the blocks were not worn down in the extreme case to much less than one-half their depth, the pavements became uneven after a period of six or eight years and required renewing.

A wood pavement, if properly constructed and maintained, posesses most of the requisites of a good pavement. It is very favorable for traction. It gives a good foothold for horses on

grades not exceeding 1 in 20. In frosty weather it is likely to become slippery, but this can be remedied by covering it with a layer of sand or fine gravel to insure a good foothold at such times. When made with impervious joints it is clean if proper attention is paid to washing and sweeping. If proper attention is not paid to washing and sweeping, wood pavement will become very filthy and be objectionable from a hygienic standpoint. When laid on a concrete base it can be relaid in small patches without danger of settling. It is less expensive than stone in first cost, but after the first two or three years costs more for maintenance.

Following are descriptions of some wood pavements which have been used quite extensively.

Nicholson Wood Pavement. (Fig. 106)

The foundation consists of a thin layer of sand, upon which are laid boards one inch thick, lengthwise of the street their ends resting on other boards, laid transversely. The flooring boards are covered on both sides with hot coal tar.

The blocks are of yellow or white pine 3 or 4 inches wide, 6 to 14 inches long, and 6 inches deep, the fibres of the wood being vertical. The lower part of the blocks is dipped in coal tar, and they are laid end to end in continuous courses across the street.

The transverse joints are three-fourths of an inch wide, battens three-fourths of an inch by one inch being laid between the rows of blocks and nailed to the blocks and flooring. The joints above the battens are then filled with a mixture of clean gravel and coal tar thoroughly rammed in.

The surface of the pavement is then coated with hot coal tar and about an inch of sand and gravel spread over it.

Stowe Wood Pavement.(Fig.107)

In the Stowe pavement, the blocks rest upon a bed of sand or gravel 4 to 6 inches thick, which has been thoroughly compacted.

They are laid in courses the same as the Nicholson, and are separated by a continuous row of wooden wedges, of the same height as the blocks. These wedges

are set with their tops at the level of the tops of the blocks. The pavement is then well rammed, and the wedges are driven down about three inches into the sand.

The joints above the wedges are then filled with a mixture of coal tar and gravel, and the surface treated as with the Nicholson.

Henson's Wood Pavement.(Fig.108)

In this pavement the foundation consists of a layer of concrete on which a strip of roofing felt is placed to give elasticity to the pavement. The courses of blocks are also separated by a similar strip of felt.

Originally, a V-shaped groove was cut along the blocks of every fourth course to give foothold, but this was dispensed with later as unnecessary.

Lloyd's Patent Keyed Wood Pavement.

In this system, the blocks, which are of pine, are grooved on each side. They are laid upon a concrete foundation, and the Portland cement grout, which is poured into the joints, fills the

grooves and forms a key to hold the blocks in position.

The Asphaltic Wood Pavement.

A layer of concrete, 6 to 9 inches thick is first laid. On this is laid a half inch coat of so-called asphalt, which is simply a coal tar composition. On this are set blocks of Baltic fir, 3 inches wide, 8 or 9 inches long, and 5 inches deep, with close longitudinal joints and one-half inch transverse joints. The joints are then filled for a depth of 2 inches with heated coal tar and the remaining depth is filled with cement grout.

The Henson, Lloyd, and Asphaltic wood pavements are English pavements, and have been used quite extensively in London.

Extracts from Specifications for Cedar Block Paving as laid in Chicago, Ill. (Fig.109)

Grading.--- Before paving the street shall be graded to conform to stakes or profiles to be given by the Engineer in charge, and thoroughly flooded, rammed

and rolled to give it a solid bed.

Paving.--- 1st. The pavement shall not be laid on any street until the material thereof shall have been made firm and unyielding, and the contractor shall assume all the responsibility therefor.

2d. A bed of clean lake shore sand, not less than three (3'') inches in depth, shall be smoothly and evenly spread over the surface of the street, and compactly rammed and rolled down.

3d. A foundation of two (2'') inch sound, common hemlock plank, to be laid lengthwise of the street close together, upon one (1'') inch by eight (8'') inch pine stringers under the ends and centers. Stringers to be firmly bedded in the sand.

4th. Upon said foundation live cedar blocks, free from bark and perfectly sound, not less than four (4'') inches nor more than eight (8'') inches in diameter and six (6'') inches in length, shall be placed on end, close laid, resting properly on their bases and well driven together. All blocks more than eight (8'') inches in diameter shall be split and the corners cut sufficiently.

to make good joints with adjacent blocks

No split blocks of less than three (3'') inches in thickness will be allowed.

All knots or excrescences must be cut off to make the blocks practically uniform in diameter throughout their length

No interstice between the blocks to be more than one and one-half (1 1/2'') inches nor less than three-quarters (3/4'') of an inch.

No square holes will be allowed, nor must two split sides come together.

The surface of the pavement must be true and uniform.

In case any loose or defective blocks shall be found in the pavement, they shall be removed and replaced by perfect blocks of proper size, and so much of the pavement as may be necessary to make the work perfect shall be taken up and relaid at the expense of the contractor.

The blocks shall be carefully inspected after they are brought on the line of the work, and all blocks or other material which, in quality or dimensions, do not strictly conform to these specifications, or which may be otherwise de-

fective, shall be rejected, and must be immediately removed from the line of the work by the contractor. The contractor shall be required to furnish such laborers as may be necessary to aid the inspector in the examination and culling of the blocks and other material, and in case the contractor shall refuse or neglect so to do, such laborers as in the opinion of the Commissioner of Public Works may be necessary will be employed, and the expense incurred shall be deducted from any money then due, or which may thereafter become due the contractor.

5th. The spaces between the blocks to be filled with clean, screened, dry, lake shore gravel, of one-fourth (1/4'') to one (1'') inch in size, the proportion of said gravel to be such as to completely fill all the interstices and shall be thoroughly rammed with proper tools, and by competent and experienced help, and again filled with the same kind of gravel and again thoroughly rammed.

In the above described ramming each interstice must be struck three full blows and driven down well. Two compe-

tent rammers must be constantly employed after each paver. No teams will be allowed on the pavement before it is properly rammed.

After ramming the pavement will be covered with hot composition, not less than one and one-half (1 1/2) gallons per square yard, and the spaces between the blocks shall be filled with the same kind of gravel flush with the top of the blocks. The tar will be distributed with a three (3) gallon kettle, the work to be done in sections as the Commission er of Public Works, or his representative may direct.

6th. After which clean, dry, lake shore gravel, about one-fourth (1/4") inch in size, shall be spread over the street in such quantity that when swept all the interstices between the blocks will be thoroughly filled; when the gravel is put on the second and third time there must be enough space left between the portions rammed once or twice from the other portions to enable the inspector to see that every part of the street is thoroughly rammed.

7th. The whole surface shall be swept

over and covered with hot composition, not less than one-half (1/2) gallon per square yard, and immediately covered with dry roofing gravel, or gravel screened from that used to fill the spaces between the blocks, said covering to be not less than one (1") inch thick. All gravel used here must be lake shore gravel, entirely free from sand or pebbles over one-half (1/2") inch in size, and dried and heated enough to prevent the chilling of the composition.

The graveling and tarring must be completed each day to within fifteen (15') feet of the end of the paving, and the top dressing to within fifty (50') feet. If the gravel and pavement become wet before the tarring is completed the same may be ordered taken up by the Commissioner of Public Works.

All composition used to be equal to Barrett & Arnald's best paving composition, distilled at 400 degrees Fahrenheit, and used at a temperature of not less than 280 degrees Fahrenheit. All gravel used to be lake shore, and dried and heated enough to prevent the chilling of the composition.

Figs.110 and 111 show two methods of laying cedar block pavements, which have been used to some extent in Duluth,Minn. and other western cities.

In the first, a 6 inch layer of concrete is used as a foundation and the blocks are set directly on this.

In the second, the foundation consists of a Telford pavement, 8 inches thick, covered with a 2 inch layer of broken stone. Over this is spread 1 inch of sand, upon which is laid a flooring of 1 inch boards to receive the blocks.

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10. Brick Pavements.

Hard burned or vitrified bricks are coming into quite extensive use as a paving material. In Holland brick pavements have been in use for over a hundred years. In the United States the first brick pavement was laid in Charleston, W.Va. less than twenty years ago.

Brick pavements may be laid on any of the forms of foundation used for stone and wood pavements.

A very common form consists of a layer of sand or gravel on which is laid a course of bricks on their side. On this

is spread a thin layer of sand as a bed for the pavement brick. The lower layer of brick need not be of as good a quality as the paving brick, but should, however, be of hard burned brick that will not be materially injured by the action of frost.

The size of the bricks varies somewhat in different cities, but 8 by 4 by 2 1/4 inches is not uncommon. They are usually made with square edges, but sometimes with rounded or beveled edges to give better foothold. Some manufacturers make a brick with the lower part thicker than the top so as to leave open joints at the surface of the pavement. Bricks are sometimes made with grooves on the sides and ends to receive the filling which is poured into the joints, thus allowing it to flow freely around the bricks.

The usual method of laying the bricks is in transverse courses with broken longitudinal joints. They may, however, be laid in any of the forms in which stone blocks are laid. The herring-bone method is sometimes used.(Fig.115)

They are almost always laid in close

contact, but the roughness of the bricks leaves a slightly open joint which is filled with sand, cement grout, or coal tar composition. The surface is covered with a thin layer of sand.

A good brick pavement possesses most of the requisites of a good pavement. It is very favorable for traction. It gives a good foothold, not usually becoming slippery with wear. When laid with coal tar or cement joints it is very clean and impervious to liquids. When the joints are filled with sand it is far cleaner than stone or wood block pavement under the same conditions, as the joints are much narrower and hence retain less mud and filth. It is somewhat noisy, slightly more so than wood, but far less than granite blocks. It can be relaid as good as new, if on a concrete foundation, when taken up to give access to pipes. It is economical in first cost when the bricks do not have to be brought from a distance, and is not expensive to keep in repair if made of a uniform quality of brick. It has been found very difficult, however, to obtain a uniform quality of brick.

and this has been the greatest objection to this kind of pavement.

Below are given extracts from specifications for brick pavements as laid in various cities.

Extracts from Specifications for Brick Pavements, Memphis, Tenn. (Fig. 112)

Concrete.-- Upon the sub-grade shall be spread the concrete foundation, composed of hard limestone, broken or crushed, to pass a two-inch ring, the same to be free of all dirt, trash, etc., clean, sharp sand mixed with fine gravel, and the best fresh Louisville cement, in the following proportions, viz.: One measure of cement and two of sand, thoroughly mixed, dry, and then made into mortar, with the least possible amount of water, and into this will be put the macadam, which shall first be well wet, and the whole worked into a concrete in such quantities as will produce a surplus of free mortar when well rammed. This proportion, when ascertained, will be regulated by measure. Each total of concrete will be thoroughly mixed, in suitable boxes, with hoes and shovels,

the mortar always to be mixed fresh before being applied to the broken stone. It will then be spread and at once thoroughly compacted by ramming with heavy cast-iron rammers, until free mortar appears on the surface; the whole operation shall be done as expeditiously as possible. The upper surface will be made exactly parallel with the surface of the pavement to be laid, by floating over the surface with cement and the straight edge. The depth of concrete consolidated, when finished, shall not be less than nine (9) inches. No walking or driving shall be permitted on the concrete when it is setting, and it shall be allowed to set for three (3) days before any pavement is laid on it.

Pavement.--- On the concrete foundation thus prepared, a bed of clean, sharp sand, free from moisture, two (2) inches deep, shall be laid. The paving bricks to be used shall be such as shall be satisfactory and acceptable to the Engineer, and shall conform strictly to the samples offered by the contractor and accepted by the Engineer and the Council. The sand must be brought to a

true and perfect surface and made to conform strictly to the grade pegs set by the Engineer, by means of a drag straight edge, seven (7) feet long, drawn over the surface, and resting on two pieces of scantling 2x4-16 feet long, having planed surfaces. The top surface of the sand bed being flush with the grade pegs. Upon this bed of sand, the paving bricks are to be laid on edge, at right angles to the line of curbs, in parallel lines, in as close contact as possible on sides and ends; the joints broken one with another, by starting at curb lines with half bricks, in alternate rows, so as to break the joints. No half or broken brick shall be laid except at the curb lines, in order to make closures, but the brick must be laid whole throughout, except as above named.

As the pavement is laid over thirty or more feet at a time, it shall be thoroughly rammed over three times with a flat iron rammer, about one foot in diameter, weighing thirty or forty pounds, which must be done by lifting and dropping the rammer vertically. When the

bricks have been rammed to a solid bearing and brought to a perfect surface, the interstices shall then be thoroughly and completely filled, from bottom to top, with distilled coal tar pitch (known as No.6), heated up to 300 degrees. All crevices must be filled, and the entire top surface covered to a depth of not less than one-fourth inch, and upon this must be spread one-fourth inch of clean, sharp sand, which must be comparatively dry and free from moisture. This sand must be thrown evenly over the boiling pitch, as rapidly as the pavement is filled in, and the pitch spread over the surface of pavement, the aim and object being to make the pavement one solid mass, which when completed, shall be practically a fixture and water tight. The bricks shall be rigidly inspected before being laid in the pavement, and all objectionable ones removed. The sand and pitch shall be acceptable, and shall also be applied as directed by the Engineer, or his Assistant, and to his entire satisfaction and acceptance. The pavement, when completed, must be smooth and conform to the grades given by the

Engineer.

Dimensions of Brick.--- Square edged, to wit: Length, 8 3/4 inches; width, 4 inches; thickness, 2 3/4 inches. Hallwood block, patent: Length, 9 inches; width, 4 inches; thickness, 3 inches.

Bricks thoroughly burned throughout to vitrification.

Extracts from Specifications for Brick Pavingon Sand Foundation, Topeka, Kas. (Fig.113)

The foundation for brick paving shall be six inches of clean river sand, free from clay, loam or other material, spread over the street and rolled thoroughly while damp, and when rolled the surface must conform exactly to the grades given by the City Engineer.

The brick for paving shall all be 2 1/4''x 4''x 8'' in size, of the same kind and quality, burnt hard and vitrified as near like the sample herewith as possible. It is expressly understood that none of the outer brick of the kiln, or the very hard, brittle brick that have been over-burnt, shall be used. None but the best of each kiln

shall be used. No brick that are warped, cracked, or that in any other way show imperfections, shall be received. The brick may be inspected at the car on the railroad track, at the brick yard where made, or on the street where the paving is to be put down. The brick are to be hauled in wagons and dumped in piles on the ground as a further test, and all broken brick to be rejected.

The brick of the top and bottom courses shall all be alike.

All brick shall be subject to the approval of the City Engineer or his duly authorized Inspector, and any brick that may be found laid in the paving not up to standard quality shall be taken up and removed by the contractor at his expense, when required to do so by the City Engineer.

On the foundation of sand the first course of brick shall be laid flat upon their 4" x 8" face, lengthways with the street.

The brick must be well and closely laid, and all joints must be broken by at least three inches lap; the joints on

the bottom layer must be thoroughly filled with dry sand, rubbed and swept in; the bricklayer must be furnished with loose sand, and will not be allowed to dig into and loosen up the six-inch foundation course. After the first course is laid, any uneveness shall be taken out by the use of a hand roller and twenty-five pound rammer, great care being exercised that the surface of the first course be true and parallel to the surface of the proposed street, as shown by the stakes of the Engineer. After this is done, then one inch of clean river sand shall be spread over the first course and brought to exact grade, as directed by the City Engineer.

On this layer of sand shall be laid the top layer of brick, on their 2''x 3" surface; the brick must be laid in even course, in close contact, and must break joints. No joints are to have less than three inches lap with the adjacent brick, the courses to run across the street or at right angles to the line of greatest travel.

At street intersections a mitre shall be used if ordered by the City Engineer.

The upper layer of brick shall be covered with sand, and swept and rubbed until all the joints are filled, and one inch of sand spread over the surface evenly and left on the pavement.

Fig.114 shows a brick pavement as laid in Davenport, Iowa.

The foundation consists of a six inch layer of broken stone thoroughly rolled, sand being used as a binding material. On this is spread a four inch layer of clean river sand and the steam roller passed over it a few times.

On the sand is placed a course of hard-burned brick on their sides. A one inch layer of sand is spread over this as a bed for the paving bricks, which are set upon edge. The bricks are 8''x 4''x 2 1/4''

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11. Asphalt Pavements.

Bitumen in one of its forms has been quite extensively used as the cementing material in street coverings. It is a hydrocarbon whose composition, according to Bousingault is,

Carbon	85 per cent.
Hydrogen	12 per cent.
Oxygen	3 per cent.

There are various forms of bitumen as follows:-

Naphtha,

Petroleum,

Maltha or Mineral Tar,

Asphalt or Mineral Pitch.

Naphtha is a colorless liquid, and asphalt is a dark brown or black solid. Between these in consistency are petroleum and maltha. There seems to be no fixed line of separation between them, each passing insensibly into the next.

Asphalt pavements may be divided in reference to the method of laying into

(1) Sheet Asphalt Pavements,

(2) Asphalt Block Pavements.

(1) There are two distinct kinds of sheet asphalt pavements.

1st. That in which the asphalt is combined naturally with the body of the pavement.

2nd. That in which the asphalt is combined artificially with the body of the pavament.

In Val de Travers in Switzerland, Seyssel in France, Vorwohle in Germany,

Ragusa in Sicily, and some other localities there is found a bituminous limestone, often called rock asphalt, which consists of a limestone naturally impregnated with a small quantity of bitumen.

It is used for paving purposes either in the form of compressed asphalt (asphalte comprime) or mastic asphalt(asphalte coule). The best foundation is a solid layer of cement concrete although a macadamized road or a stone block pavement may be used.

The compressed asphalt is laid in the following manner. The rock asphalt is quarried and broken in a rock crusher to a size of two or three inches in diameter. These pieces are then ground to a powder between rollers, and this is heated to a temperature of about 250 or 260 degrees. It is then carried in covered carts to the point where it is to be laid and spread on the concrete foundation. It is leveled to the required thickness with iron rakes and then rammed with hot cast iron rammers. It is then smoothed with hot smoothing irons after which it is rammed and

rolled until cold.

The asphalt is usually two or two and one-half inches thick after being compressed and the powder should be spread about two fifths thicker to allow for the compression.

The surface of the concrete should be perfectly dry when the hot powder is applied, otherwise steam will be formed which will injure the pavement.

Some rocks contain too large and some too small a per cent of bitumen for paving purposes, and in this case a mixture of two rocks can be made which will contain the required amount. To produce the best results it should contain about 10% of bitumen but this varies somewhat with the climate, a greater amount being needed in a cold than in a warm climate. The reason for this is that an asphalt containing a large per cent of bitumen becomes soft at a high temperature, while one containing a small per cent becomes hard and brittle at a low temperature.

The compressed asphalt is used almost entirely in Europe; Paris, Berlin and London, each having many miles of

streets paved with it.

In Kentucky, a sandstone containing about 10% of bitumen is found. This has been used to some extent prepared in the same manner as the limestone, not, however, with much success thus far.

In California also, a bituminous sandstone is found which is used for paving. It is disintegrated by steam, and is then spread upon the foundation and rolled.

The following test for rock asphalt was proposed by W.H.Delano in a paper read before the Inst. of Civil Engineers in 1880. ''A specimen of the rock freed from all extraneous matter having been pulverized as finely as possible should be dissolved in sulphuret of carbon, turpentine, ether, or benzine, placed in a glass vessel and stirred with a glass rod. A dark solution will result, from which will be precipitated thepulverized limestone. The solution of bitumen should then be poured off. The dissolvent speedily evaporates, leaving the constituent parts of the asphalt, each of which should be weighed, so as to determine the exact proportion.

The bitumen should be heated in a lead bath and tested with a porcelain or Baume thermometer to 428 degrees Fah. There will be little loss by evaporation if the bitumen is good, but if bituminous oil is present the loss will be considerable. Gritted mastic should be heated to 450 degrees Fah. The limestone should next be examined. If the powder is white and soft to the touch, it is a good component part of asphalt but if rough and dirty, on being tested with reagents, it will be found to contain iron pyrites, silicates, clay etc. Some asphalts also are of a spongy or hygrometrical nature. Thus, as an analysis which merely gives so much bitumen and so much limestone may mislead. It is necessary to know the quality of the limestone and of the bitumen''.

Mastic asphalt is very little used for payements at the present day, although it was quite extensively used in Europe several years ago. It was not found to give satisfactory results for this purpose, but it makes excellent foot-paths and floors. We will leave the description of its preparation until the sub-

ject of foot paths is reached.

The second kind of asphalt pavement, that in which the asphalt is combined artificially with the body of the pavement. is the one most commonly laid in the United States.

The cementing material is natural asphalt or mineral pitch. The principal supply comes from the island of Trinidad in the British West Indies. It is also found in the island of Cuba, in California, and in some parts of Europe.

The asphalt of Trinidad occurs in what is called the ''Pitch Lake''. This so-called lake is simply a level deposit of asphalt about 140 feet above sea level, containing about 114 acres. It is hard enough to bear the weight of a man on any part of its surface, but the consistency is such, that excavations made to the depth of two or three feet are entirely obliterated after a few days by the gradual rising of the bottom of the excavation. The material as obtained from the lake is of a dark brown color, and contains about 40% of bitumen, 40% of earthy and vegetable impurities, and 20% of water.

The asphalt is brought to this country in the crude state and is refined by heating in tanks to a temperature of about 300 degrees. This drives off the water and causes the lighter impurities to rise to the surface while the heavier sink to the bottom.

The asphalt thus formed is too brittle for use, hence there is added to it about 15% of heavy residuum oil obtained from the distillation of petroleum. This mixture is called ''asphaltic cement'' and is very tough. This cement is mixed with sand and finely pulverized limestone to form the wearing surface of the pavement. The proportions of the substances used vary somewhat with difference in climate, between the following limits,

Asphaltic Cement	12	to	16%
Sand	83	to	67%
Pulverized Carbonate of Lime	5	to	17%
	100		100

The sand and asphaltic cement are heated separately to a temperature of about 300 degrees Fah. The cold carbonate of lime is then mixed with the hot sand and this and the asphaltic cement

are then thoroughly mixed.

The powder resulting from this mixture is spread upon the concrete foundation at a temperature of about 250 degrees, and rolled until thoroughly compacted, a wash of hydraulic cement being swept over it while the rolling is in progress to give it a light color.

Sometimes the asphalt is put on in two layers, the lower one being one half inch thick and containing a slightly larger per cent of the asphaltic cement. This is called the cushion coat and was formerly supposed to give a slight degree of elasticity to the pavement. It is generally dispensed with, however, as being unnecessary, and the entire thickness, usually two and one-half inches, is applied in one layer.

A sheet asphalt pavement is more favorable for traction than any other pavement. When kept clean, asphalt gives a good foothold under ordinary conditions of weather. When covered with wet mud it is very slippery.

Observations made in the United States show that a horse will travel the following distance before slipping:-

On asphalt	583 miles.
On granite	413 miles.
On wood	272 miles.

Observations made in London show the following;-

On asphalt	191 miles.
On granite	132 miles.
On wood	330 miles.

It is claimed that the artificial mixture is less slippery than the rock asphalt on account of the large per cent of sand that it contains. A sheet asphalt pavement should not be used, however, on a grade steeper than about 1 in 50. It is free from dust and mud unless brought on from other sources. It is impervious and smooth, hence, it can be easily cleaned. It is nearly noiseless. It is difficult to take up but can be relaid in as good condition as ever. It is quite expensive as to first cost but is economical as to maintenance. Under a moderate traffic an asphalt pavement will last about 15 years.

The specifications of the Sicilian Asphalt Paving Co. for paving with rock asphalt (Fig.116) are as follows,-

Grading.--- The present pavement shall

be removed, and the subsoil shall then be excavated and removed to the depth of 8 inches below the top line of the proposed pavement. Soft or spongy places not affording a firm foundation shall be dug out, refilled with good earth, clean gravel or sand, and well rammed, so as to make such filling compact and solid, and the entire road-bed thoroughly rolled with a heavy roller.

Foundation.--- Upon the road-bed thus prepared shall be laid a foundation of hydraulic cement concrete 6 inches in thickness, to be made as follows: One measure of cement, equal to the best quality of freshly burned Rosendale cement, and two of clean, sharp sand, shall be well mixed dry, and then made into a mortar with the least possible amount of water. Broken stone, thoroughly cleaned from dirt and drenched with water, but containing no loose water in the heap, shall be immediately incorporated with the mortar in such quantities as will give a surplus of mortar when rammed. This proportion, when ascertained, shall be regulated by measure. Each batch of concrete shall

be thoroughly mixed. It shall then be spread and at once compacted by ramming until free mortar appears upon the surface. The whole operation of mixing and laying each batch shall be performed as quickly as possible. No gravel shall be used in the concrete, but only angular fragments of stone, having rough faces obtained by fracture, and of a size that will pass through a 2-inch ring. The upper surface of the concrete shall be made exactly parallel with the surface of the asphalt pavement to be laid thereon, and shall be 2 inches below the grade of the top of the finished pavement and exactly parallel thereto.

Wearing Surface.--- Upon this foundation, when sufficiently dry, the wearing surface, or pavement proper, shall be laid.

The material used shall be a mixture of from three to four parts of the natural bituminous lime-stone rock from the Sicilian mines at Ragusa, with one part of that from the German mines at Vorwohle, both rocks being equal in quality and composition to that mined by The United Limmer and Vorwohle Rock Asphalte

Company, Limited, and it shall be prepared and laid as follows:

1. The lumps of rock shall be crushed and pulverized, and the powder passed through a fine sieve, the two sorts of rock being thoroughly mixed in the mill. Nothing whatever shall be added to or taken from the powder obtained by grinding bituminous rock.

2. This powder shall be heated upon an open heater, constructed of fire-proof brick, to a temperature of about 160 degrees Fahrenheit, and shall be brought to the ground at such temperature in suitable carts, and there carufully spread on the concrete foundation previously prepared, to such depth, that after having received its ultimate compression, it will have a thickness of two inches.

3. It shall then be skillfully compressed by heated hand-rollers and rammers until it shall have the required thickness of two inches.

4. The surface shall then be rendered even by heated smoothers.

5. The pavement shall fin ally, after completion, be rolled for two or three

days with a heavy horse-roller.

Railroad Tracks.--- When street or other railroad tracks run through or across streets to be paved with asphalt, a line of granite paving blocks, each not more than 5 nor less than 4 inches in width, shall be set upon a bed of 6 inches of concrete, between the rails and the asphalt. The joints between the blocks shall be filled with cement. The upper surface of the blocks shall be flush with the highest part of the rails. The line of granite blocks shall be of one uniform width, and the upper surface of the pavement shall be 1/2 inch higher than that of the blocks.

Repairs Free of Charge.--- The Asphalt Company shall, during the period of..... years from the date of the acceptance of the work, execute free of charge any and all repairs of the pavement that may become necessary through legitimate wear and tear, or from natural causes.

Other Repairs.--- The Asphalt Company shall, during the said period, lay and restore the pavement over trenches made for laying water and gas pipes, sewers, and for other purposes, at a price ten

per centum above the original contract price, and when once so laid and restored maintain the same in the same state of repair and for the balance of the time as agreed to for the other parts of the pavement. The asphalt removed for the purpose of digging said trenches shall become the property of the Asphalt Company.

The specifications of the Barber Asphalt Paving Co. for their Class A. Standard Pavement (Fig.117) are as follows;-

1st. We propose to lay Trinidad Asphalt Pavements two and one-half (2 1/2) inches in thickness when compressed, with a base of hydraulic cement-concrete six (6) inches in depth.

Roadbed.---2nd. All unnecessary material will be removed from the street; soft or spongy places, not affording a firm foundation, will be dug out and refilled with good earth, well rammed, and the entire roadbed will be thoroughly rolled.

Foundation.---3rd. Upon the roadbed thus prepared will be laid a bed of hy-

draulic cement-concrete six inches in thickness, to be made as follows:

One measure of American cement, equal to the best quality of freshly burned Rosendale cement, and two of clean, sharp sand will be thoroughly mixed dry, and then made into mortar with the least possible amount of water; broken stone, slag or gravel thoroughly cleaned from dirt, drenched with water, but containing no loose water in the heap, will then be incorporated immediately with the mortar in such quantities as will give a surplus of mortar when rammed. This proportion, when ascertained, will be regulated by measure. Each batch of concrete will be thoroughly mixed. It will then be spread and at once thoroughly compacted by ramming until free mortar appears upon the surface. The whole operation of mixing and laying each batch will be performed as expeditiously as possible. The upper surface will be made exactly parallel with the surface of the pavement to be laid. Upon this base will be laid the wearing surface, or pavement proper, the cementing material of which is a paving cement

prepared from the best quality of pure Trinidad Asphaltum, obtained from the so-called pitch - or asphalt - lake in the Island of Trinidad, unmixed with any of the products of coal tar.

Wearing Surface.---4th. The wearing surface will be composed of:

Asphaltic Cement	from 12	to 15
Sand	" 83	" 70
Pulverized Carbonate of Lime	" 5	" 15
	100	100

In order to make the pavement homogeneous, the proportion of asphaltic cement must be varied according to quality and character of the sand. The carbonate of lime may be reduced, or omitted entirely, when suitable sand can be obtained.

The sand and asphaltic cement are heated separately to about three hundred degrees Fahrenheit. The pulverized carbonate of lime, while cold, is mixed with the hot sand in the required proportions, and is then mixed with the asphaltic cement at the required temperature, and in the proper proportions, in a suitable apparatus, which will effect

a perfect mixture.

The pavement mixture, prepared in the manner thus indicated, will be laid on the foundation in one coat; it will be brought to the ground in carts or wagons at a temperature of about 250 degrees Fahrenheit; it will then be carefully spread, by means of hot iron rakes, on the foundation, in such manner as to give a uniform and regular grade, and to such depth that after having received its ultimate compression it will have a thickness of two and one-half inches. The surface will then be compressed by rollers, after which a small amount of hydraulic cement will be swept over it, and it will then be thoroughly compressed by a steam roller; the rolling being continued as long as it makes an impression on the surface.

Should there be a railroad track on the street, the edge of the asphalt pavement adjacent to the track will be protected by a line of stone paving blocks on each side of the rail.

5th. The pavement shall be laid under proper official inspection. It shall be guaranteed for a period of five years

from the date when it is opened to traffic, and during said period all defects in the pavement due to its proper use as a roadway shall be repaired and made good without additional expense.

The Barber Asphalt Paving Co. Class F pavement (Fig.118) has a 4 inch layer of cement concrete, a 1½ inch binding layer of bituminous concrete, and a 1 1/2 inch wearing surface of Trinidad Asphalt.

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(2) Asphalt Block Pavement. Compressed blocks, made of a mixture of asphaltic cement and crushed limestone, have been used for some time in this country. They are 12 inches long, 4 inches wide and 5 inches deep.

The method of manufacturing them is as follows.- The limestone is crushed until it contains no pieces larger than one quarter inch in diameter, quite a portion of it being reduced to powder. It is then heated to a temperature of about 250 degrees Fah. and mixed with about 10% of its weight of Trinidad asphaltic cement which is at about the same temperature. It is then put in a

mold and subjected to a pressure of about 3000 pounds to the square inch.

These blocks are laid in the same manner as stone blocks, sometimes on a concrete foundation but more commonly on sand or gravel. (Fig.119) The blocks are laid in close contact and usually without any filling in the joints, as the nature of the material is such that the joints will become practically water tight after the traffic has passed over the pavement a short time.

For very light traffic asphalt blocks make a satisfactory pavement, but they wear too rapidly for heavy traffic. Their first cost, when the concrete foundation is omitted, is usually a little less than that of sheet asphalt.

Before leaving the subject of asphalt, I wish to call attention to the fact that in Europe the nomenclature established by Leon Malo is adhered to by many engineers. This gave the name, asphalt, only to the bituminous limestone which we have called rock asphalt, and not to the mineral pitch which we call asphalt.

12. Coal Tar Pavements.

Coal tar has bee tried as a substitute for the asphaltic cement in the construction of pavements, but without much success. The coal tar contains volatile oil which evaporates in a short time causing the pavement to crumble to powder. The only coal tar pavements which have met with any degree of success are those which contain a certain amount of asphaltic cement. They are all, however, much inferior to asphalt. The so-called Vulcanite Pavement is the best of this class and has been laid with a fair degree of success, especially in Washington, D.C.

The specifications for this pavement are as follows,-

1. The vulcanite asphaltic pavement will be eight and one-half (8 1/2) inches in thickness, as follows. The wearing surface will be one and one-half (1 1/2) inches in thickness when compacted, with a bituminous base and binder seven inches in depth.

2. The space over which the pavement is to be laid will be excavated to the depth of eight and one-half (81/2) inches below the top surface of the pavement

when completed. Any objectionable or unsuitable material below the bed will be removed, and the space filled with clean gravel or sand well rammed. The bed will then be trimmed so as to be exactly parallel to the surface of the new pavement when completed, and the entire road-bed will be thoroughly rolled with a heavy steam-roller. Upon the foundation will be laid the base and binder, seven (7) inches in thickness, in the following manner:

3. The ''base'' will be composed of clean broken stone, that will pass through a three (3) inch ring, well rammed, and rolled with a steam-roller to the depth of five (5) inches, and thoroughly coated with hot paving cement composed of No. 4 tar distillate in the proportion of about one (1) gallon to the square yard of pavement.

4. The second or ''binder'' course will be composed of clean broken stone, thoroughly screened, not exceeding one and one-quarter (1 1/4) inches in the largest dimensions, and No.4 tar distillate. The stone will be heated by passing through revolving heaters, and

thoroughly mixed by machinery with the distillate in the proportion of one gallon of distillate to one (1) cubic foot of stone.

5. The ''binder'' will be hauled to the work spread upon the base course at least two (2) inches thick, and immediately rammed and rolled with hand and heavy steam-rollers while in a hot and plastic condition.

6. The wearing surface will be one and one-half (1 1/2) inches thick when compacted, made of paving cement, composed of twenty-five (25) per cent of asphalt and seventy-five (75) per cent of distillate mixture, with other materials as follows: Clean sharp sand will be mixed with pulverized stone of such dimensions as to pass through a one-quarter (1/4) inch screen in the proportion of two to one.

To twenty-one (21) cubic feet of the above named mixture will be added one peck of dry hydraulic cement, one quart of flour of sulphur, and two quarts of air-slacked lime. To this mixture will be added three hundred and twenty (320) pounds of paving cement, to compose the

wearing surface.

7. The material will be heated to about 250 Fahr. - the paving cement in kettles, the sand and stone, etc. in revolving heaters. They will be thoroughly mixed by improved machinery, and the mixture carried upon the work, when it will be spread upon the binder course two (2) inches thick with hot iron rakes and other suitable appliances, and immediately compacted with tamping-irons, hand and steam rollers, while in a hot and plastic state. The surface will be finished with a dusting of dry hydraulic cement rolled in.

8. The pavement so constructed must be a solid mass, eight and one-half (8 1/2) inches thick, and will be thoroughly rolled and cross-rolled until it has become hard and solid.

9. The pavement shall be equal in every respect to that laid on K Street, between Ninth and Eighteenth Streets, N.W Washington, D.C., in 1874 and 1875.

FOOTPATHS.

Sidewalks or other footpaths may be constructed of any of the following materials,-

1. Earth.
2. Broken Stone.
3. Gravel.
4. Plank.
5. Brick.
6. Stone.
7. Cement Concrete.
8. Asphalt.
9. Coal Tar.

1. Earth footpaths are objectionable as they become muddy in wet weather. If made of a material that will pack well, as a mixture of sand and clay, they are very satisfactory for dry weather and make a very pleasant walk.

Special attention should in any case be paid to the drainage of the subsoil, other wise the walk will become a mass of mud when the frost is coming out of the ground.

2. Broken Stone makes an excellent walk for parks, suburban streets, streets of villages and small cities, or where a foot path is needed on a country road.

They should be constructed in much the same manner as a carriage road except that a less thickness of metal is required, and the stones should be smaller The subsoil should be well drained and the metal applied in layers and thoroughly rolled with a horse roller. A thickness of from 4 to 6 inches on a good dry soil will make a good walk. The top layer should be of very fine stone or screenings, not suitable for the roadway.

3. Gravel may be used instead of broken stone, and with nearly as good results. It should be from 4 to 6 inches thick. The surface layer should not contain an excess of earthy material, as this will become mud in wet weather. The walk should be thoroughly rolled.

4. Plank sidewalks are very common, especially where lumber is cheap. They are usually made of 2 inch plank, laid either in a transverse or longitudinal direction. (Fig. 120) The former is the more common method in the western cities while the latter is generally used in this section of the country.

The planks should be spiked to timbers

resting upon the ground 2 to 4 feet apart.

5. Brick sidewalks are extensively used in some cities. The bricks should be hard burned but not necessarily as hard as for street pavements. They are usually laid on a bed of sand or gravel. They may be laid on either their side or edge transversely across the walk, or in herring-bone style. (Fig. 121) If used for side walks on business streets, where heavy loads are likely to be dropped upon them from wagons, they should be laid upon edge as for street pavements. The joints are commonly filled with sand. A filling of cement grout is preferable for heavy traffic as it gives a better bond between the bricks and thus prevents unequal settlement.

The specifications for laying brick sidewalk in Boston are as follows,-

Laying Brick Sidewalk.

All new bricks that may be required to pave the sidewalks will be furnished to the Contractor by the City.

The bricks in the existing sidawalks

shall be carefully taken up and placed in piles by the Contractor. Such of these bricks as, in the opinion of the Superintendent of Streets, aresuitable for the work, shall be culled by the Contractor, from those taken up, and re-laid in place of new bricks.

The Contractor shall excavate the sidewalk to a depth of 10 in. below the finished grade of the brick paving and the material at this sub-grade shall be thoroughly compacted by rolling or ramming.

Any objectionable material below this sub-grade shall be excavated, and the space filled with thoroughly compacted gravel. Care must be taken in excavating to preserve the proper slope parallel with the proposed surface.

Upon this prepared sub-grade will be spread a layer of fine gravel which shall be 4 in. in thickness after being thoroughly compacted by rolling or ramming, and which shall be free from stones larger than 3/4 in. in their greatest dimensions.

After this foundation has been thoroughly compacted, another layer of clean

sharp sand 4 in. in thickness, to serve as a bed for the bricks, shall be spread upon the sidewalk foundation,upon which the bricks will be laid.

Special care shall be taken to make the surface of this sand-bed parallel with the surface of the proposed brick paving, and in laying the bricks the pavers must not stand or kneel upon this sand bed.

The bricks shall be laid on their---- and either at right angles with the line of the street or in herring-bone style, as the Superintendent of Streets may direct. The bricks are to be laid with close joints, and each course of bricks is to be of uniform width and depth, and so laid that all longitudinal joints shall be broken by a lap of at least 2 in. When thus laid the bricks shall be immediately covered with clean, fine, dry sand, screened through a sieve having not less than twenty meshes to an inch. The bricks will then be carefully rammed by placing a plank over several courses and ramming the plank with a heavy rammer or hammer.

The ramming will be continued until

the bricks reach a firm, unyielding bed, and present a uniform surface with proper grade and slope. Any lack of uniformity in the surface must be corrected by taking up and relaying. When the ramming iscompleted, a sufficient amount of fine, dry sand, as above described, shall be spread over the surface and swept or raked into the joints.

Suitable areas shall be left unpaved around the trees in the sidewalk, if such exist, as directed by the Superintendent of Streets.

Edges of the brick sidewalk when not abutting against the curb or buildings will be finished by a continuous row of bricks set on edge.

6. Stone. Slabs of granite 6 to 8 inches thick are often used for sidewalk on business streets. (Fig.122) They are especially useful where there is an open space under the sidewalk, as they can be made to span the distance from the curb to the building if the walk is narrow, or can be supported on transverse beams if the walk is wide.

Flagstones from 2 to 4 inches thick laid directly on the soil or on a bed of

sand or gravel make an excellent walk. In Liverpool the sidewalks are laid with flagstones 3 inches thick, with a surface not less than 2 by 3 feet.

7. Cement Concrete. Concrete side-walks are used quite extensively in some parts of the United States and make a good substitute for stone. They may be made either in place, or molded in blocks and laid in the same manner as flagstones.

If made in place, a foundation of sand or gravel, or better still broken stone (Fig.123) should be prepared and consolidated. On this the concrete should be laid in two layers having a total thickness of 3 or 4 inches, the first layer being composed of cement, sand and broken stone, and the surface layer, which should be about 1/2 inch thick, of cement and sand only. The concrete should be spread upon the foundation and thoroughly rammed.

It is laid in sections of 20 or 25 superficial feet, boards set on edge being used as a form in which to mold the slab. Portland cement should be used in the top layer but a good American cement

will do for the bottom layer. For the surfacelayer a fine crushed granite may be used instead of sand. Traffic should not be allowed upon the walk until the cement has hardened.

The blocks of cement are made in various sizes and shapes. Two very common forms are shown in Fig.124. They are laid on a bed of sand, gravel, or broken stone.

8. Asphalt. Footpaths of asphalt although not very common in this country, are quite extensively used in Europe. They may be laid in a single sheet (Fig. 125) or in the form of compressed blocks (Fig.126)

The sheet form may be constructed of the natural rock asphalt or of the artificial mixture.

The foundation should be firm andunyielding, either cement or bituminous concrete, or some other solid material. The concrete foundation for a footpath need not exceed 3 or 4 inches in thickness.

The natural rock may be laid either in the compressed or mastic form.

The method of laying the compressed

asphalt is the same as that already described for constructing pavements, except that the layer of asphalt need not be more than 3/4 to 1 inch in thickness.

The preparation of the mastic asphalt which has been used to some extent for street pavements, is as follows:- The natural rock is ground to powder as for the compressed asphalt. It is then mixed with from 5 to 8% of mineral pitch like that obtained at Trinidad. The pitch is first refined and heated in a large tank and the powdered rock is added gradually, the mixture being stirred constantly. The mixture is then poured into molds and allowed to cool, forming blocks weighing about 50 pounds each. In this form it is transported to the point where it is to be used. The blocks are then broken into small pieces weighing two or three pounds and melted, 2 or 3 per cent of mineral pitch being added to replace that lost by evaporation. To the mixture is then added a certain amount of sand or finely crushed stone. The mastic is then poured upon the surface of the concrete foundation and spread with a wooden trowel. A small amount of sand is then dusted over the

surface and the walk is ready for traffic as soon as it has become cool.

When the mastic is to be used near where it is prepared, it is not necessary to mold it into cakes, but the sand is added to the mixture of powdered rock and bitumen, and applied to the foundation the same as above.

Sidewalks of asphalt have a life in London, under heavy traffic, of from 12 to 15 years, the compressed form being somewhat more durable than the mastic.

In this country the artificial mixture has been used to some extent, prepared in the same manner as for street pavements. The thickness of the asphalt surface is usually about 1 inch.

Following are the specifications of the Barber Asphalt Paving Co. for laying such a sidewalk.

1st. We propose to lay Trinidad Asphalt Sidewalks and Driveways one (1) inch in thickness when compressed; with a base of broken stone three (3) inches in depth.

Preparation of Bed.--- 2nd. The space over which the Sidewalk or Driveway is

to be laid will be excavated to a depth of four (4) inches below the finished grade of sidewalk.

All unnecessary material will be removed from the walk; soft or spongy places, not affording a firm foundation, will be dug out and refilled with good earth, well rammed, and the entire roadbed will be thoroughly rolled.

Foundation.--- 3rd. Upon the bed thus prepared will be laid a base composed of clean broken stone, slag or gravel, that will pass through a 2 1/2 inch ring, spread to a thickness of four (4) inches thoroughly compressed by rolling with a heavy roller to a thickness of three (3) inches. It will be thoroughly coated with coal tar residuum commonly known as No. 4 Paving Composition, or other bituminous material equally good, in the proportion of about ten gallons to one cubic yard of stone. The upper surface will be made exactly parallel with the surface of the pavement to be laid. Upon this base will be laid the wearing surface or pavement proper, the cementing material of which is Paving Cement prepared from the best

quality of pure Trinidad Asphaltum, obtained from the so-called pitch - or asphalt - lake in the Island of Trinidad, unmixed with any of the products of coal tar.

Wearing Surface.--- 4th. The wearing surface will be composed of:

Asphaltic Cement	from	12 to 15
Sand	"	83 to 70
Pulverixed carbonate of Lime	"	5 to 15
		100 100

In order to make the pavement homogeneous, the proportions of Asphaltic Cement must be varied according to quality and character of sand. The carbonate of lime may be reduced or omitted entirely, when suitable sand can be obtained.

The sand and Asphaltic Cement are heated separately to about three hundred degrees Fahrenheit. The Pulverized carbonate of lime, while cold, is mixed with the hot sand in the required proportions, and is then mixed with the Asphaltic Cement at the required temperature, and in the proper proportions, in a suitable apparatus, which will effect a perfect mixture.

The pavement mixture, prepared in the manner thus indicated, will be brought to the ground in carts or wagons, at a temperature of about 250 degrees Fahrenheit; it will then be carefully spread, by means of hot iron rakes and in such a manner as to give a regular and uniform grade, and to such a depth that after having received its ultimate compression it will have a thickness of one inch. The surface will then be compressed by rollers, after which a small amount of hydraulic cement will be swept over it, and it will then be thoroughly compressed by a heavy roller; the rolling being continued as long as it makes an impression on the surface.

5th. The pavement shall be laid under proper official inspection. It shall be guaranteed for a period of five years from the date when it is opened to traffic, and during said period all defects in the pavement due to its proper use as a roadway shall be repaired and made good without additional expense.

Compressed blocks, formed of a mixture of Trinidad asphalt and crushed lime-

stone in the same proportions as for asphalt paving blocks, make an excellent walk. They may be laid on a bed of sand or gravel and retain an even surface on account of the adhesion between the edges of the blocks. They are made in two shapes, square and hexagonal, 8 inches across and 2 1/2 inches thick. (Fig 126)

9. Coal Tar. Sidewalks made of a mixture of coal tar and gravel, or broken stone are quite satisfactory for surburban streets. They are usually laid in two or three layers having a total thickness of 3 to 4 inches, the top layer being composed of tar and sand.

In Newton,Mass. the coal tar sidewalks are constructed in three layers.(Fig.127)

The foundation course consists of a layer of clean gravel not over 2'' in diameter, thoroughly coated with hot coal tar paving cement. This layer is not less than 2 1/2'' thick after being thoroughly compacted by ramming and rolling.

The binding course comsists of clean screened gravel,not over 1'' in diameter, mixed with coal tar composition in the proportions of one cubic foot of the

gravel to one gallon of the coal tar. This is spread while hot upon the foundation to such a thickness that after being rolled it shall have a thickness of at least one inch.

The wearing surface consists of clean, screened, sharp sand heated and mixed with hot coal tar in the proportions of about 85% of the sand and 15% of the coal tar. The sand is of such a size that not over 20% remains on a sieve of 20 meshes to the inch, and about 60% remains on a sieve of 40 meshes to the inch. Not over 5% will pass through a sieve of 60 meshes to the inch.

The mixture is spread while hot over the binding course, and thoroughly rolled to a thickness of one half inch. The surface is then sprinkled with sand and again rolled.

Under the subject of footpaths a word may be said in regard to crosswalks.

Planks are sometimes used for crosswalks in places where stone can not be easily obtained, but they wear rapidly and should not be used except as a temporary expedient.

Crosswalks of coal tar laid in the

same manner as sidewalks but somewhat thicker are used to some extent in suburban towns.

The best material for crosswalks is stone. As usually laid it is in slabs from 6 to 8 inches thick, 14 to 24 inches wide and not less than 3 feet long. If more than one width is required, two or more rows may be laid side by side, breaking joints in the direction across the line of the walk. Very often the rows are separated from each other by one or more rows of stone paving blocks.

A stone that does not polish under traffic is best for the purpose as the smooth surface of the crossing stones affords, at best, a very poor foothold for horses. In Liverpool this difficulty is overcome to a certain extent by cutting a groove along the center line of the surface of the stone.

Crosswalk stones are set on abed of sand or gravel,.or, in the case of a paved street, usually on the same foundation as the pavement.

CURBS AND GUTTERS.

Along the edge of the footpath, between it and the road, some sort of a curb is usually set. The simplest form and one that does very well for gravel walks, is a simple border of sods sloping up from the gutter to the edge of the walk which is six or eight inches above it.

Another simple border for the sidewalk of a country road consists of a single row of cobblestones .

The most common form of curb is made of stone in lengths of three feet or more. It varies in width and depth in different localities, ranging from 4 to 8 or even 12 inches wide, and from 1 to 3 feet deep.

Stone curbs are usually set on a foundation of sand or gravel. When the foundation of the adjacent pavement is of concrete or broken stone, it is quite common to have a similar foundation for the curb. This is especially advisable with a shallow curb.

The curb should be hammer dressed on the top and down the face as far as it is exposed, also on the back for a depth

of three or four inches to give a true surface for the sidewalk to butt against

Curbs of concrete made in slabs are used in some cities. They are made of cement, sand and broken stone in much the same manner in which the concrete sidewalks are made. The face of the curb should be made of cement and sand only.

With brick pavements a curb of the same material has been used, though not to any great extent.

Gutters are constructed in either of two general forms. The most common one is formed by the intersection of the slope of the roadway with the face of the curb, the lowest point being close to the curb. In the other form the gutter is a concave channel, and the curb is sometimes omitted.

With a macadamized or gravel roadway, the gutter is sometimes left without any paving.

A very common form of gutter for such a macadam street consists of cobblestone laid as for a street pavement to a width of two or three feet. Cobble stone gutters are also used in some of the west-

ern cities when the roadway is paved with cedar blocks.

The usual method of constructing the gutter with wood and stone block as well as brick and asphalt pavement is simply to extend the paving to the face of the curb. With a block pavement, five or six rows of blocks are sometimes laid in a longitudinal direction. This arrangement gives a better channel for the water, but the joints are likely to develop ruts as they are in the line of the traffic.

Sometimes slabs of stone 15 or 18 inches wide and 3 or 4 inches thick are used to form a gutter. An objection to these is that, if they are not very carefully bedded, they will tip under heavy loads. Another objection is the tendency to form ruts along their edges which is not entirely done away with by making the stones alternately of different widths, as 15 and 18 inches, as is sometimes done.

Gutters as well as curbs are sometimes made of concrete. They are made both in the shape of slabs, and also in combination with the curb.

Figs.128 to 132 show some forms of gutters that were used in New York, Central Park. In Fig.128 the curb and gutter are both of dressed blue stone. In Fig. 129 the curb is of rough quarry stone and the gutter of cobble stone. In Fig.130 the curb and gutter are of brick. In Fig.131 the curb is blue stone and the gutter of rough quarry stone. In Fig.132 the curb and gutter are rough quarry stone.

Fig. 133 shows a curb and gutter used to some extent in Providence,R.I. for a macadam street. The gutter is of cobble stones covered with a layer of concrete.

In Liverpool,(Fig.134) the curb stones are not less than 3 feet long or 12 inches deep, and are 6 inches thick at the top and7 inches thick,5 inches below the top. The gutter is made of stone slabs 3 inches thick, 16 inches wide and not less than 3 feet long.

Fig.135 shows the method of setting curb on a concrete foundation as used in Albany,N.Y. on a street paved with asphalt.

The following are the Boston specifi-

cations for curbstones or edgestones.

The edgestones are to be of Quincy, Cape Ann, or other equally good granite, but all of the same color, and are to be cut in lengths of not less than 6 feet, to be free from bunches and depressions, and to have horizontal beds; the ends to the entire depth to be squared with the top, and so cut as to be set with joints of not more than 3/8 of an inch without mortar; the edgestones to be out of wind. The hammered surfaces are to be full to line. The edgestones are to be 7 inches wide on top and 20 inches deep; they are to be hammered on top, fine-pointed 3 inches down on the back, and squared with the top, and fine-pointed 10 inches down on the face; the remainder of the face is to be rough-pointed to a true and even surface. The face is to be cut square with the top.

Each and every length of edgestone to be equal in quality and finish to the sample portion on exhibition in the Superintendent of Streets'office at the time of making this contract, and to be satisfactory to said Superintendent of Streets.

The following are the Chicago specifi-

cations,-

Curb stone shall be of the best quality of lime stone, free from cracks, seams, and sand pockets, straight and not less than four (4') feet long, three (3') feet deep, and five (5'') inches thick when dressed.

Top edge to be full and square, and neatly bush hammered. The face shall also be neatly bush hammered not less than twelve (12'') inches down from the top.

The ends to be dressed smooth, so as to make close joints full thickness of the stone not less than one (1') foot down from the top.

The back side of the stone shall be dressed to a uniform thickness of five (5'') inches at least three (3'') inches down from the top.

The bottom shall be straight and firmly set upon blocks of flat stone not less than one (1') foot by eight (8'') inches by six (6'') inches thick.

The corner or catch basin stones at the corners of the streets must be cut to a true circle of three (3') feet radius, must be neatly bush hammered eighteen (18'') inches down from the top

and the top must also be neatly bush hammered and free from drill holes or other defects.

The inlet to the catch basins must be four (4'') inches deep, fourteen (14'') inches wide, cut from the bottom of the stone to within nine (9'') inches of the top.

Fig. 136 shows a combination curb and gutter made of concrete used in Duluth, Minn. with cedar block pavement on a concrete foundation.

Fig. 137 shows a concrete curb and gutter used in Topeka, Kas. The specifications for these are as follows,-

Cement Curb and Gutters.

Cement or artificial stone curb and gutters shall be made of the best quality of imported Portland cement, in good condition, free from lumps, ground fine, so that eighty-five per cent, will pass through a No. 120 sieve, and mixed with two parts of sand, shall stand a tensile strain of 160 pounds per square inch seven days after it is made up and kept immersed in water, and 230 pounds thirty days after being made up; or the neat cement shall stand a tensile strain of

300 pounds per square inch after six days in water and one day in air, and shall have at the same time a crushing strength of two thousand (2.000) pounds per square inch.

Dimensions and Shape of Curb.

The cement curb shall be twenty inches deep, five inches thick, and four feet long, as shown on plan. The stones must have true, straight surfaces and edges, with corners rounded to a radius of one-half inch, except the upper face corner shall have a radius of one inch; the ends must be true, with full square corners, and when set there shall be not to exceed one-fourth inch between the stones. Corners will be made with a face radius of two feet, twenty inches in depth, five inches thick at the ends, with corners rounded with one-half inch radii, except the upper face corner shall have a radius of one inch, as shown on plan.

Material and Proportions.

Two parts of clean, coarse, sharp river sand to one part of the best Portland cement, shall be used in making cement stone for all its parts. No ve-

riation will be allowed for any portion of the work.

Dimensions and Shape of Cement Gutters

The cement stone for gutters shall be thirty inches wide, five inches thick, and four feet long; and the divisions between the pieces must be perfect, complete and at right angles to the length of the curb and gutter, so that any piece, after properly hardening, may be lifted from its place without wedging itself.

Measurement

Cement curbing and guttering will be measured, allowing the actual length to the intersection of the curb and gutter at corners, and no additional allowance will be made for curved corner stones nor for cutting to fit man-holes, catch-basins, stop-boxes, gas fixtures, or other improvements that cannot be readily moved, and all fitting shall be done to the satisfaction of the City Engineer.

Mixing.

The materials, of the quality and in the proportions heretofore specified, shall be thoroughly mixed while dry, until the mixture has an even, uniform color; water shall then be added slowly

by sprinkling while the mixture is being thoroughly stirred and mixed, until an evenly dampened and complete mortar suitable for moulding is obtained. The mortar thus prepared shall be immediately placed in the mould as rapidly as it can be thoroughly rammed, until the mould is full and the top is finished in the form heretofore specified.

All measures of cement or sand shall be struck; they shall be level full, and not heaped or deficient in quantity.

Cement work shall not be mixed or laid when the temperature is below thirty-five degrees, and all cement work shall be protected against damage, by fencing or otherwise, until hardened and the work accepted by the City Engineer, Mayor and Council.

All work is to be carefully set to the lines and grades as given by the City Engineer or has assistants, and the same maintained until accepted by the City Engineer, Mayor and Council.

Samples and Tests.

The contractor shall furnish samples of cement from each barrel or package to the City Engineer for test, and any

cement found deficient in quality, tensile or crushing strength, shall be rejected and immediately removed from the work, and no more of the same kind or brand shall be used until permission is given by the City Engineer after further tests which show the cement equal to the requirements.

Miles of Pavement in Various Cities.

	Albany, Jan. 1892.	Allegheny, Jan. 1892.	Boston, Jan. 1892.	Buffalo, Jan. 1891.	Chicago, Jan. 1892.	Cincinnati, Jan. 1892.
Broken Stone and Gravel	2	12	344	101	256	142
Cobble and Rubble Stone	31	91	6			95
Stone Block	19	2	69	140	23	45
Wood Block					482	2
Brick					1	1
Asphalt	7	1	5	106	13	9
Coal Tar						
Total	59	106	424	347	775	294

Miles of Pavement in Various Cities.-Continued

	Cleveland, Jan. 1892.	Des Moines, Jan. 1892.	Detroit, Jan. 1892.	Kansas City, Jan. 1892.	Los Angeles, Jan. 1892.	Lincoln, Jan. 1892.
Broken Stone and Gravel	7	1		4	93	
Cobble and Rubble Stone	1		16			
Stone Block	67	16		3	2	1
Wood Block	5	22	140	51		5
Brick	8	8	2	2		10
Asphalt	1		11	9	6	
Coal Tar						
Total	89	47	169	69	101	16

Miles of Pavement in Various Cities.- Continued.

	Louisville, Sept.1891.	Milwaukee. Jan 1892	Minneapolis, Jan.1892.	Newark, Jan.1892.	New Haven Jan 1892.	New York Jan.1891.
Broken Stone and Gravel	113	1		11	31	134
Cobble and Rubble Stone	14			25		3
Stone Block	17	13	4	15	4	321
Wood Block		35	34			
Brick						
Asphalt	7		1	1		16
Coal Tar						
Total	151	49	39	52	35	474

Miles of Pavement in Various Cities.- Continued.

	Omaha, Jan. 1892	Philadelphia Jan. 1892	Providence, Jan. 1892.	St. Louis, April, 1890.	St. Paul, Jan. 1892.	Washington Jan. 1892.
Broken Stone and Gravel		95	118	290		49
Cobble and Rubble Stone		478	10			11
Stone Block	19	138	11	42		26
Wood Block	25			5	36	
Brick	4	31				
Asphalt	16	51	1	4	4	68
Coal Tar						38
Total	64	793	140	341	40	192

Cost of Pavements per Square Yard.

Broken Stone, Cobble Stone and Stone Block.

	Broken Stone.	Cobble Stone.	Stone Block: On Concrete or Br. Stone.	Stone Block: On Sand or Gravel.
Albany, N.Y.	1.50	1.40	4.08	3.00
Allegheny, Pa.	.39	1.10	3.05	2.70
Boston, Mass.			4.70	3.05
Bridgeport, Conn.	× .28			
Buffalo, N.Y.	2.20		3.04	2.25
Cincinnati, O.			4.25	
Columbus, O.		.70		
Dayton, O.			3.73	
Detroit, Mich.			3.90	
Evansville, Ind.	1.70			
Fairfield, Conn.	× .43			
Fanwood, N.J.	†† 1.00			
Indianapolis, Ind.	‡ 1.50	.75		
Kansas City, Mo.			2.85	2.54
Kingston, R.I.	† .50			
Los Angeles, Cal.				2.25

Cost of Pavements per Square Yard.

Broken Stone, etc. - Continued.

	Broken Stone.	Cobble Stone.	Stone Block: On Concrete or Br. Stone.	Stone Block: On Sand or Gravel.
Louisville, Ky.		1.70	3.00	
Milwaukee, Wis.				2.00
Nashville, Tenn.			2.75	
New Haven, Conn.	.46		2.41	
Omaha, Neb.				1.95
Paterson, N.J.	× .40	.75		
Philadelphia, Pa.	1.35			2.50
Providence, R.I.		.60	4.00	2.50
Saginaw, Mich.		.70		
Springfield, Mass.	‡1.00			
St. Paul, Minn.				2.10
Union Township, N.J.	††1.16			
Washington, D.C.	1.00		3.25	

×4'' macadam. †8'' macadam. ‡10'' macadam.

×× 15'' macadam. ††12'' Telford.

Cost of Pavements per Square Yard.

Wood Block.

	On Concrete.	On Broken Stone.	On Boards or Planks.	On Sand or Gravel.
Detroit, Mich.	1.90		1.80	1.70
Duluth, Minn.	1.90	1.20	1.10 ×1.30	
Fort Wayne, Ind.		1.10		
Grand Rapids, Mich.	2.00		×1.30	1.00
Indianapolis, Ind.				1.70
Lincoln, Neb.	1.71			
Milwaukee, Wis.			1.15	
Minneapolis, Minn.			.86	
Saginaw, Mich.			.92	
Sioux City, Ia.			1.22	
St. Paul, Minn.	1.75		1.20 ×1.40	
Topeka, Kas.	2.25			

All the above are cedar block pavements with the exception of those marked thus × which are the Nicholson.

Cost of Pavements per Square Yard.

Brick.

	One Layer.			
	On Concrete.	On Broken Stone.	On Sand or Gravel.	Two Layers.
Boston, Mass.			2.75	
Buffalo, N.Y.	2.50			
Cincinnati, O.	2.60			
Cleveland, O.			1.35	
Columbus, O.		2.30		
Des Moines, Ia.				1.60
Detroit, Mich.	2.75			
Evansville, Ind.	2.25	1.95		1.70
Indianapolis, Ind.	2.50			
Kansas City, Mo.	1.60			
Little Rock, Ark.	2.25		1.60	2.15
Lincoln, Neb.				1.75
Memphis, Tenn.	2.68			
Omaha, Neb.	1.76			
Philadelphia, Pa.			2.05	
Topeka, Kas.				1.54

Cost of Pavements per Square Yard.

Asphalt.

	Sheet.	Block.
Albany, N.Y.	3.15	
Allegheny, Pa.		2.64
Altoona, Pa.	3.00	
Boston, Mass.	3.64	3.10
Buffalo, N.Y.	2.70	
Cincinnati, O.	3.00	
Columbus, O.	2.75	
Dayton, O.		3.32
Detroit, Mich.	3.20	
Grand Rapids, Mich.	2.90	
Indianapolis, Ind.	2.83	
Kansas City, Mo.	2.65	
Lancaster, Pa.		2.48
Los Angeles, Cal.	2.70	
Louisville, Ky.	3.50	
Omaha, Neb.	2.48	
Philadelphia, Pa.	2.25	2.00
Salt Lake City, U.	3.00	
St. Paul, Minn.	2.75	
Syracuse, N.Y.	2.70	
Topeka, Kas.	2.80	
Washington, D.C.	2.25	2.00

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Summary of same,
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Also Eng.and Bld.Rec.Aug.20&27,1887.

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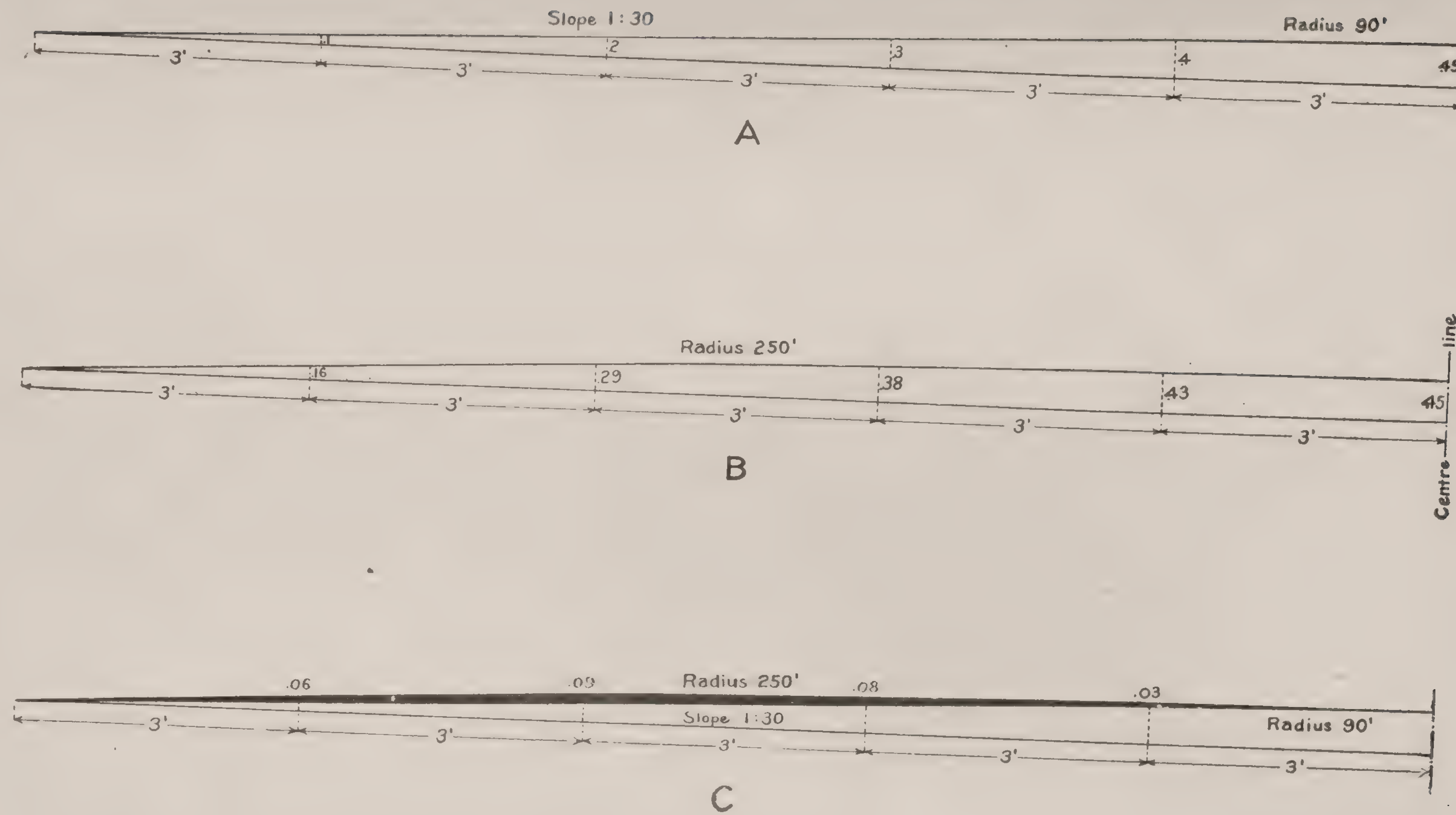


Fig. 1. TWO FORMS OF CROSS-SECTION OF ROADWAY.

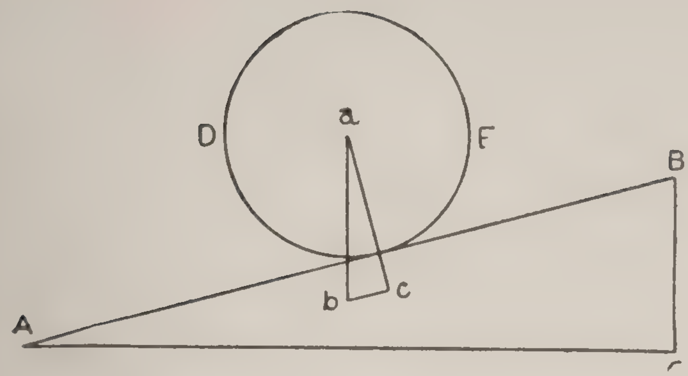


Fig. 2.

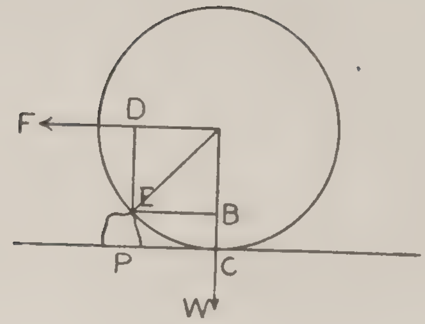


Fig. 3.

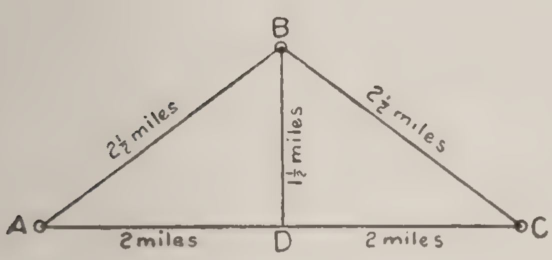


Fig. 4.


Fig. 13.

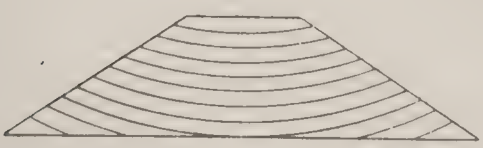
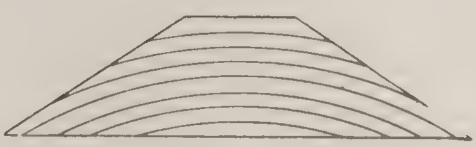


Fig. 11.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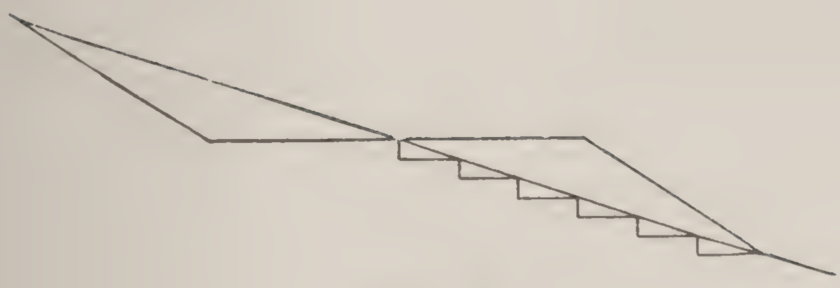
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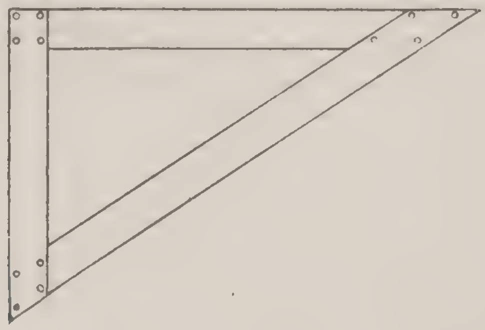
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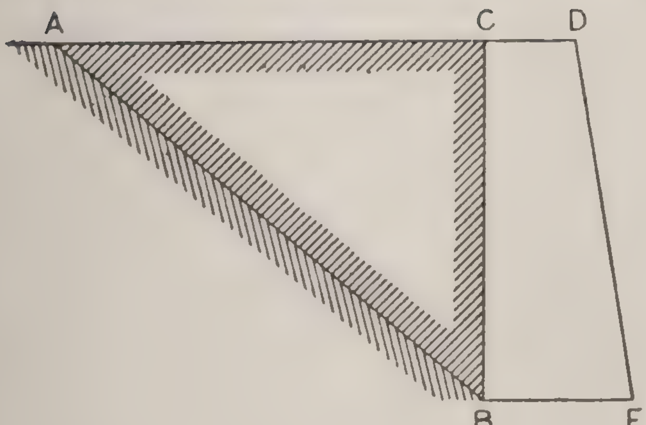

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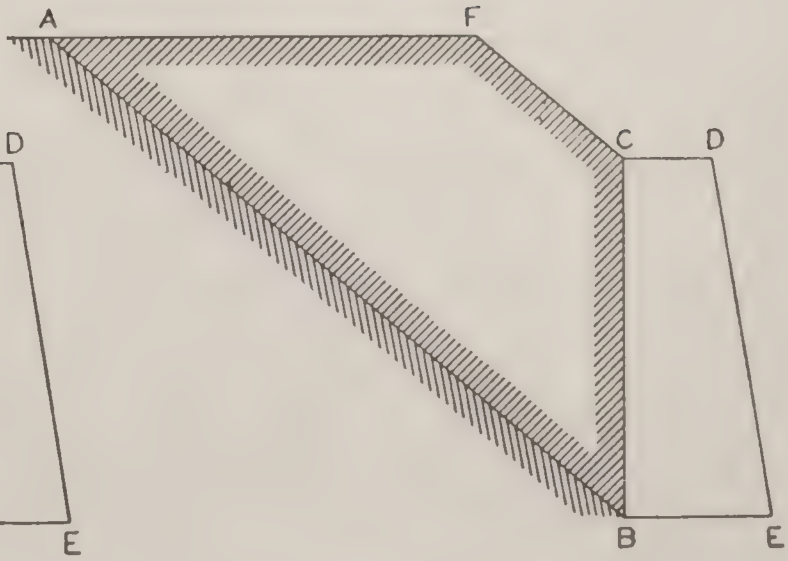

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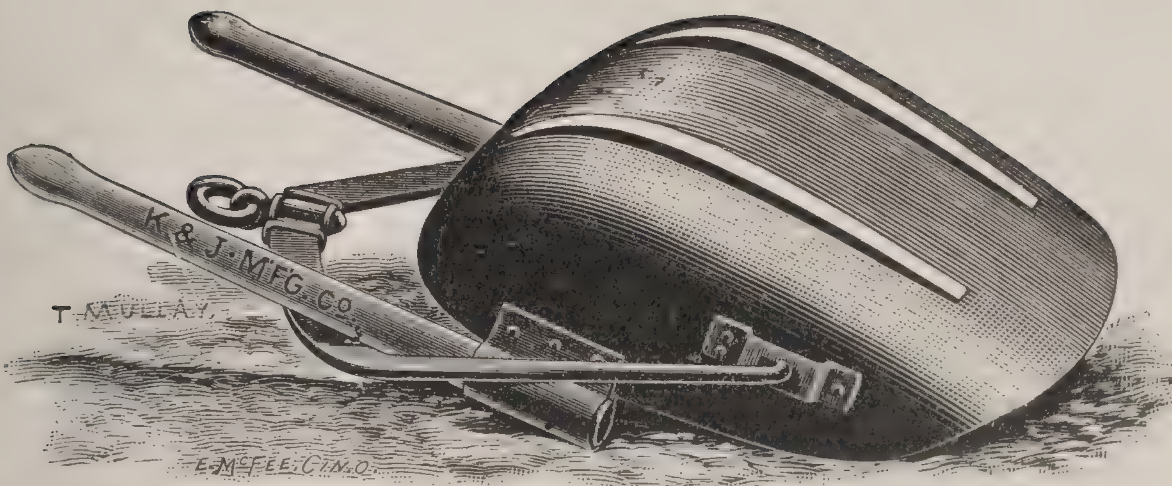

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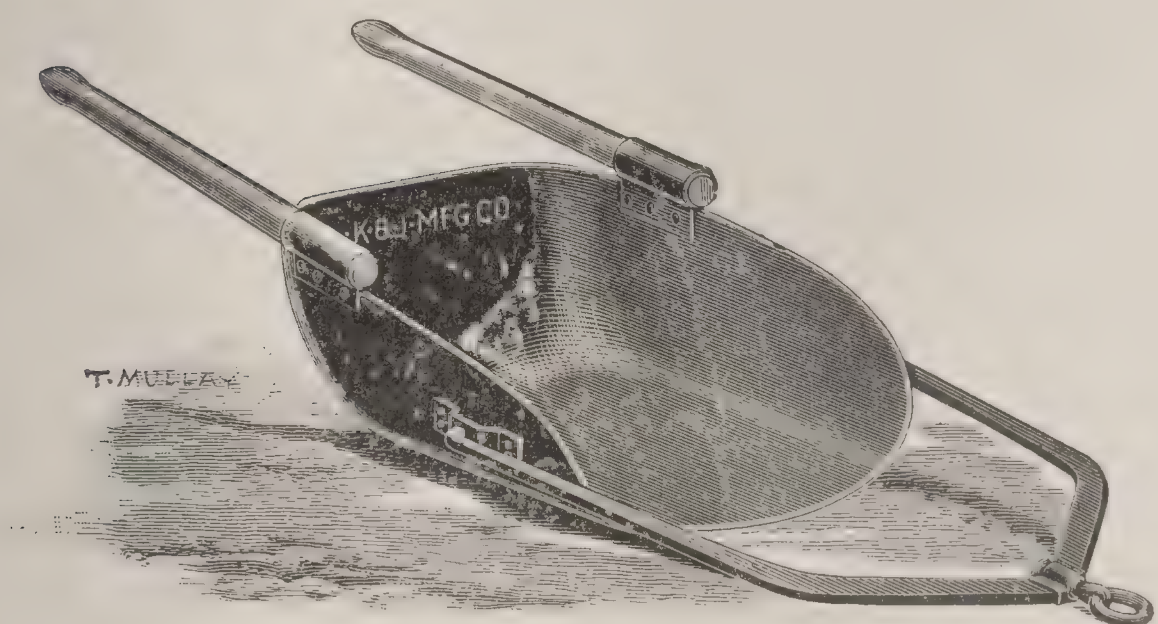

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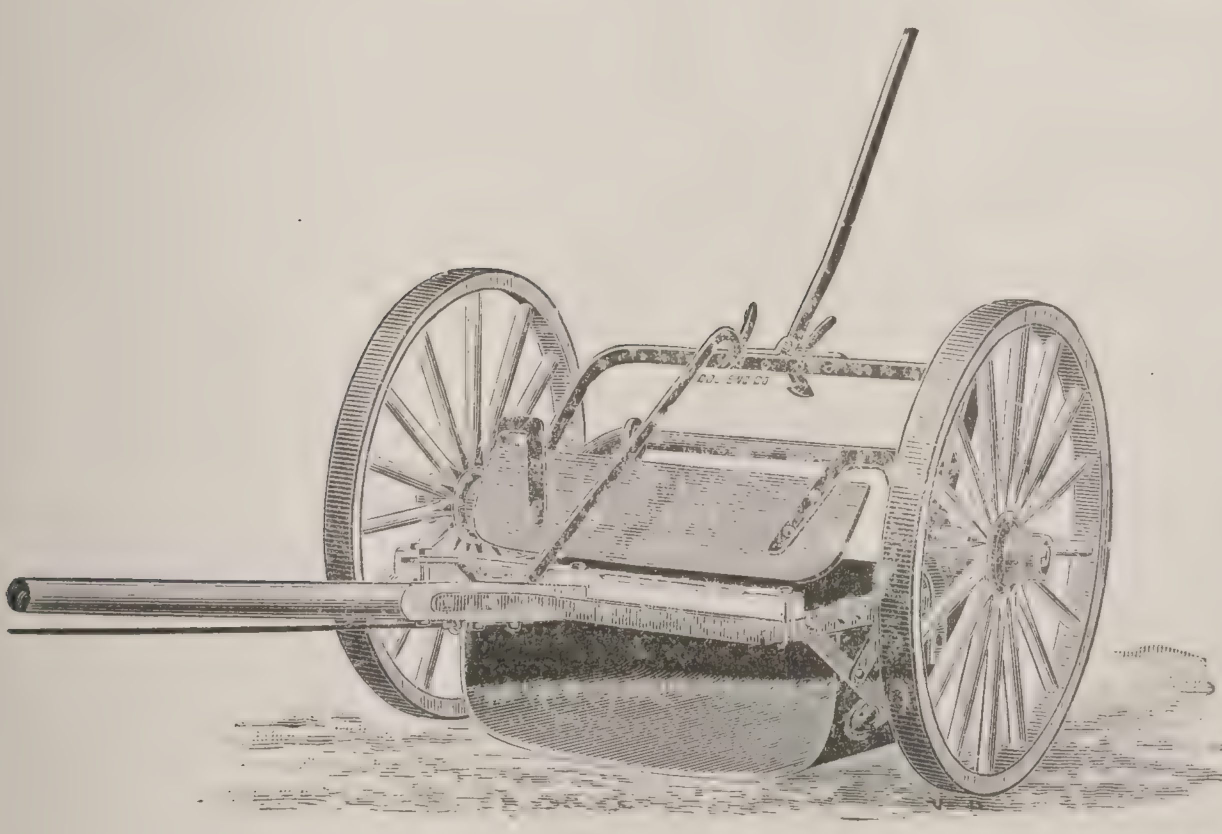

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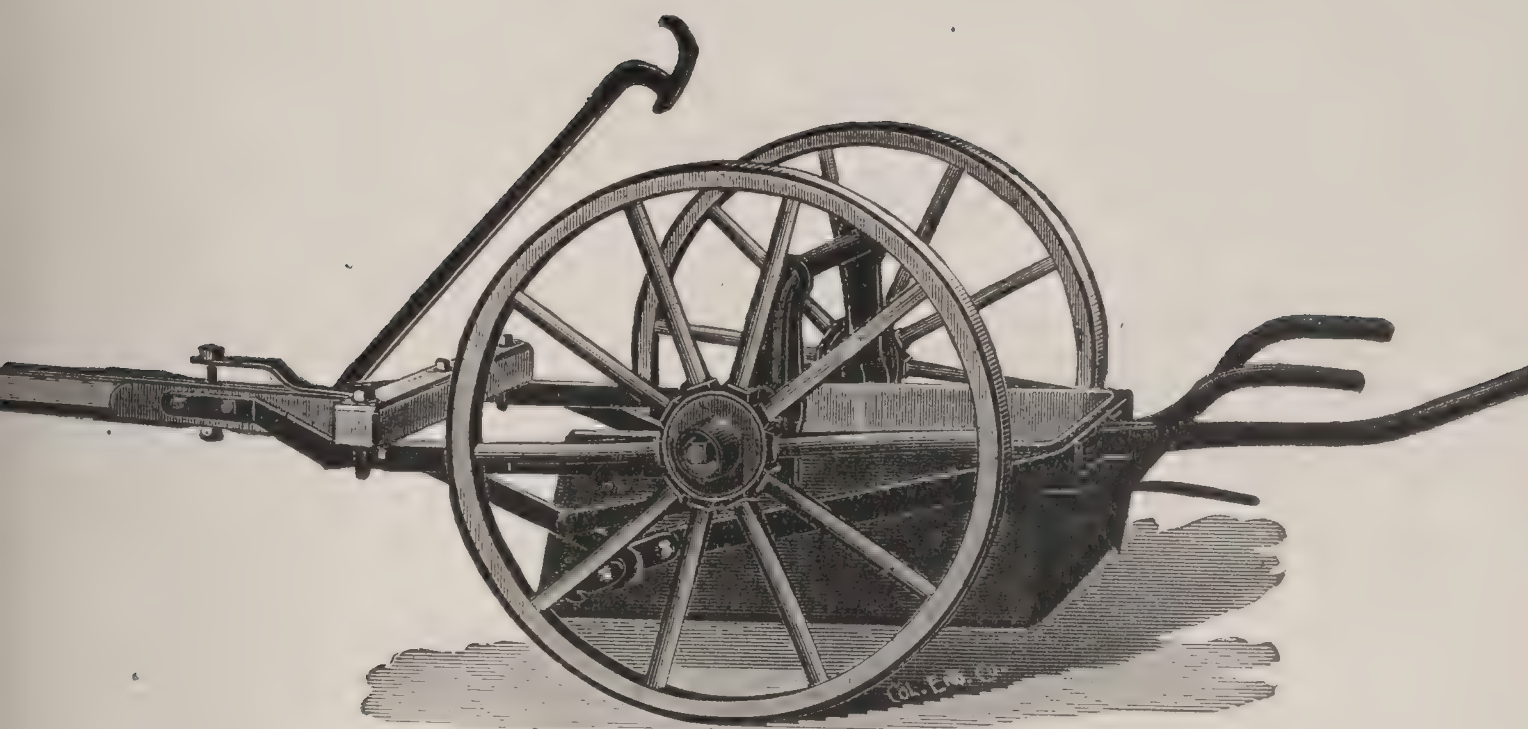

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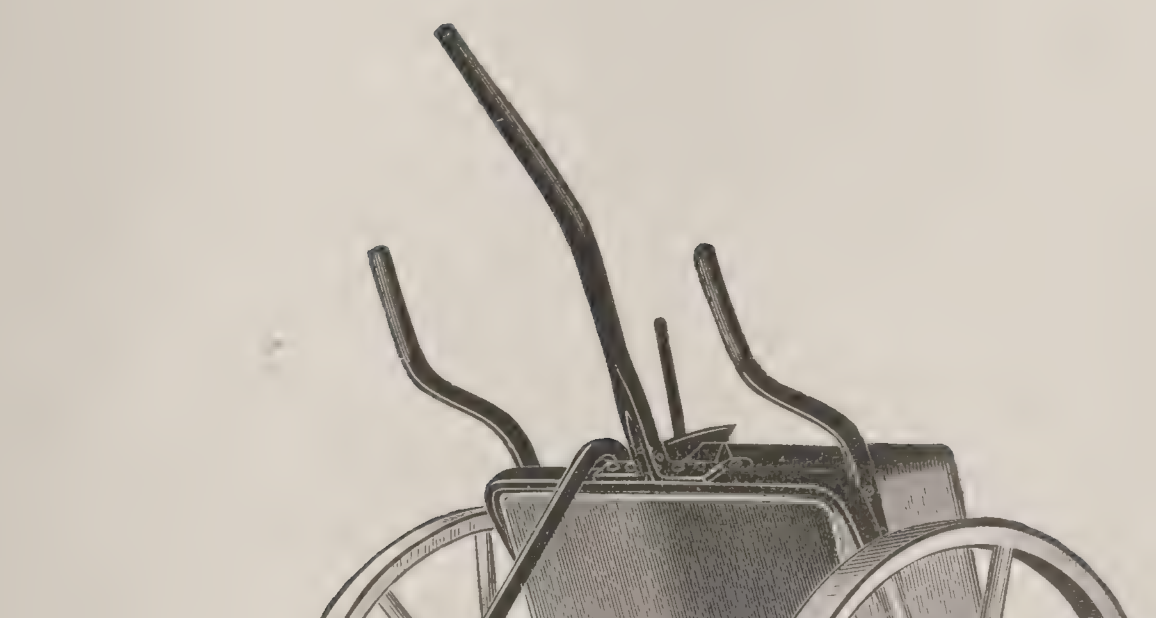

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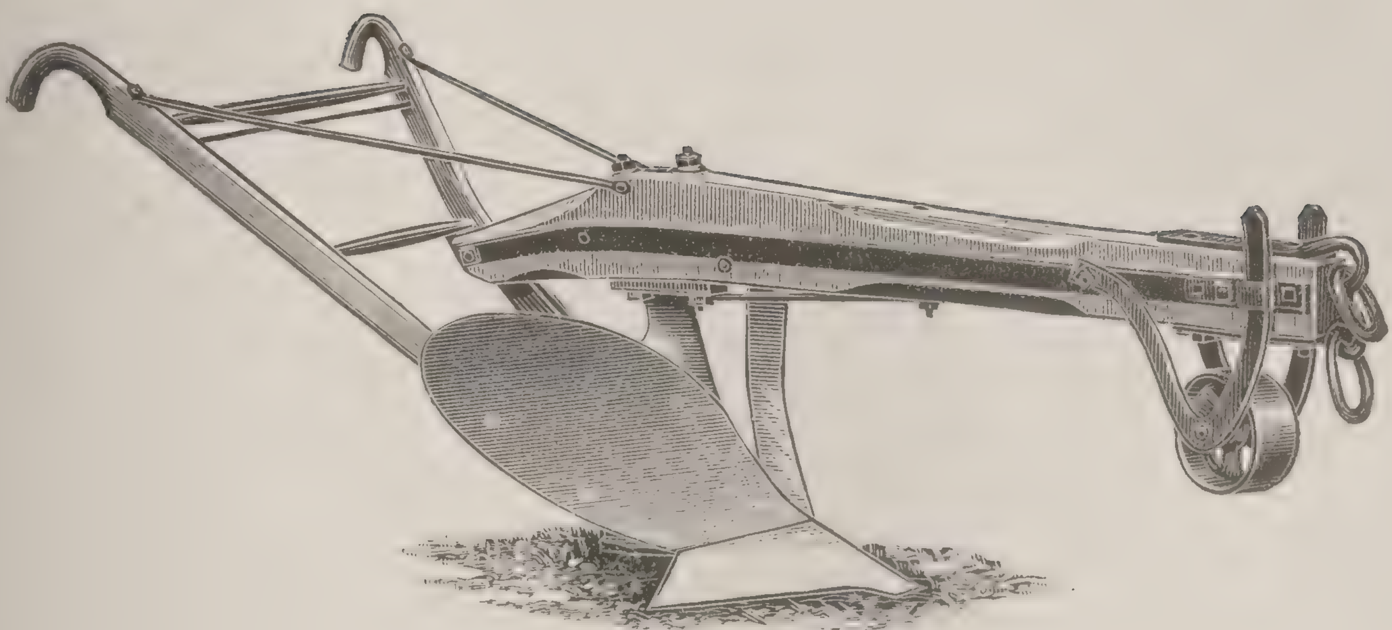


F g. 10.

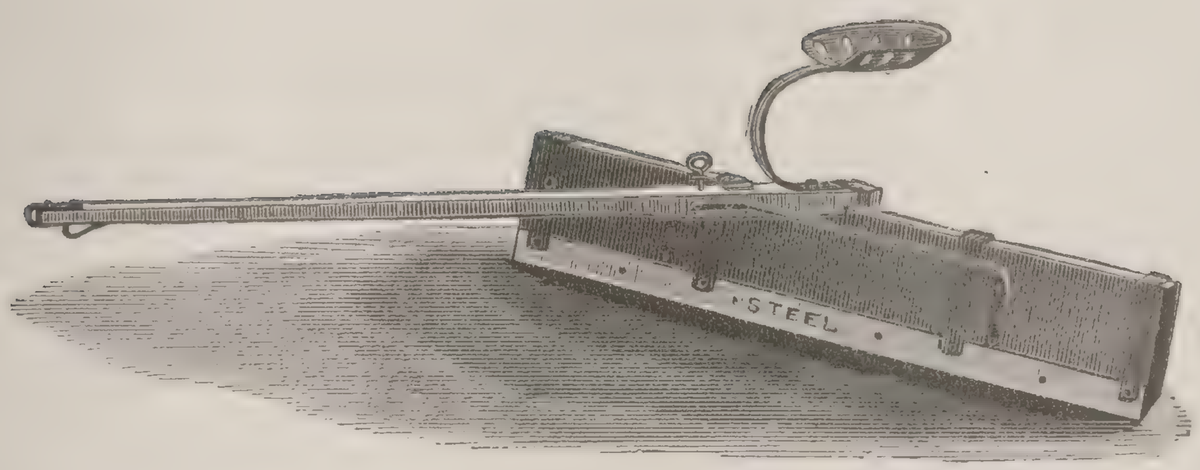


Fig. 10a.

The Scrapers, Plow and Leveler, as shown in Figs. 5—10a, are manufactured by the Kilbourne & cobs Manufacturing Co., of Columbus, O.

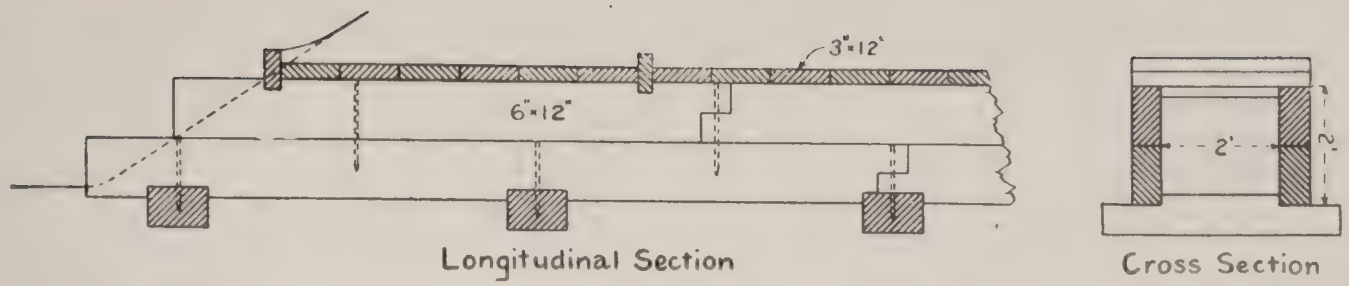


Fig. 18. 2 ft. x 2 ft. WOODEN CULVERT.

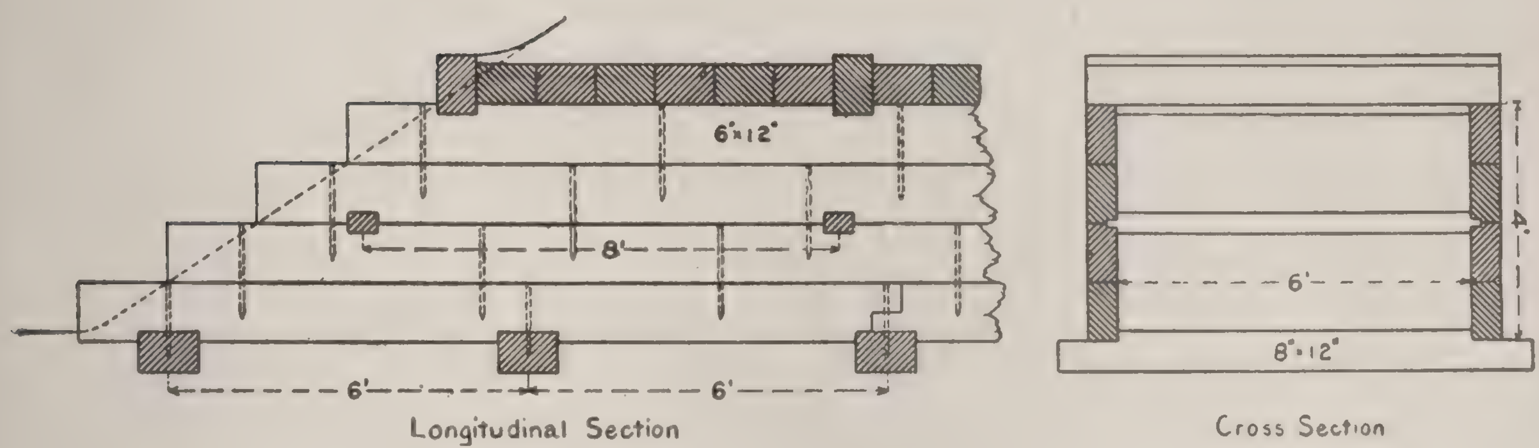


Fig. 19. 4 ft. x 6 ft. WOODEN CULVERT.

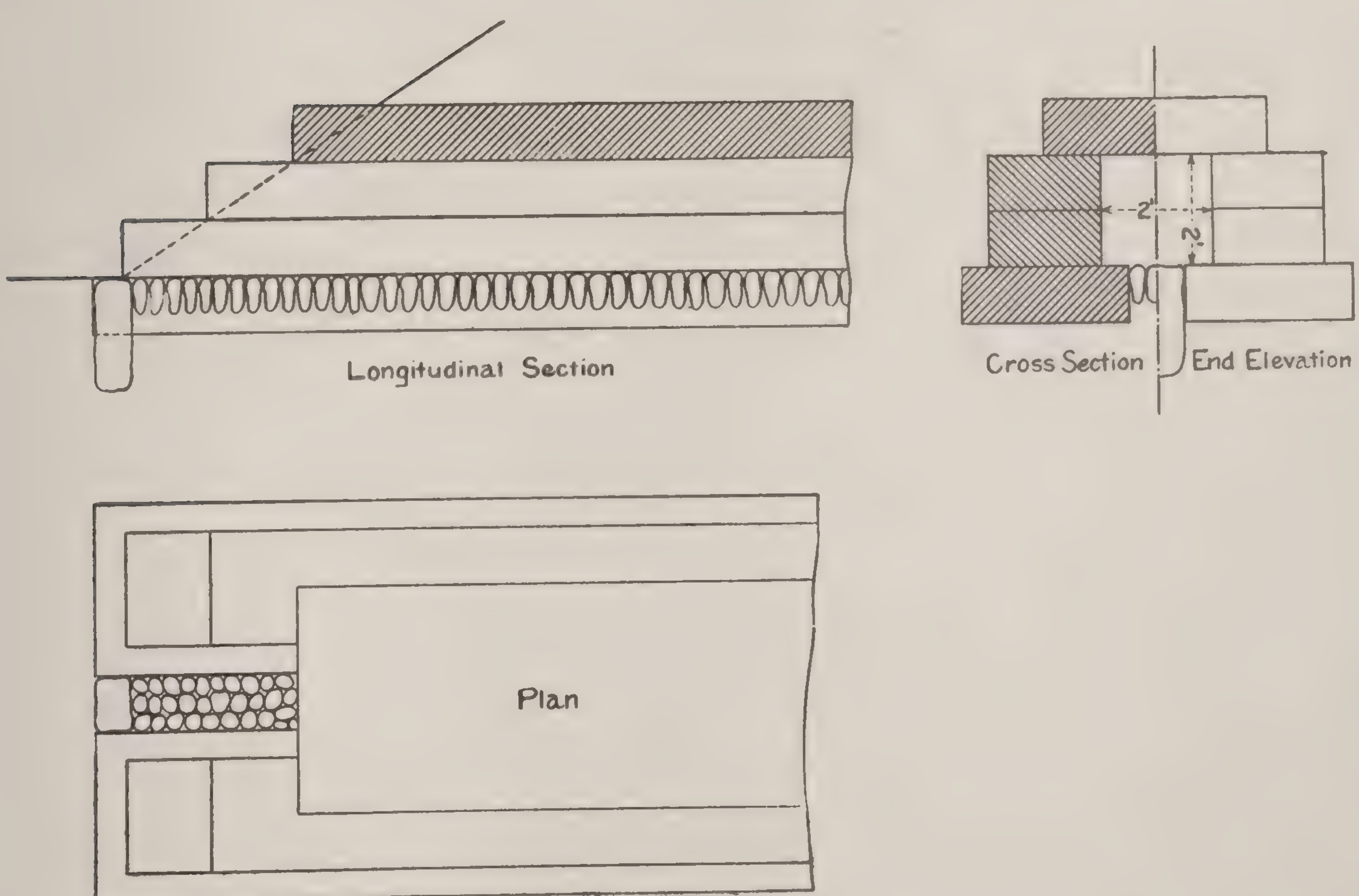


Fig. 20. 2 ft. x 2 ft. STONE BOX CULVERT.

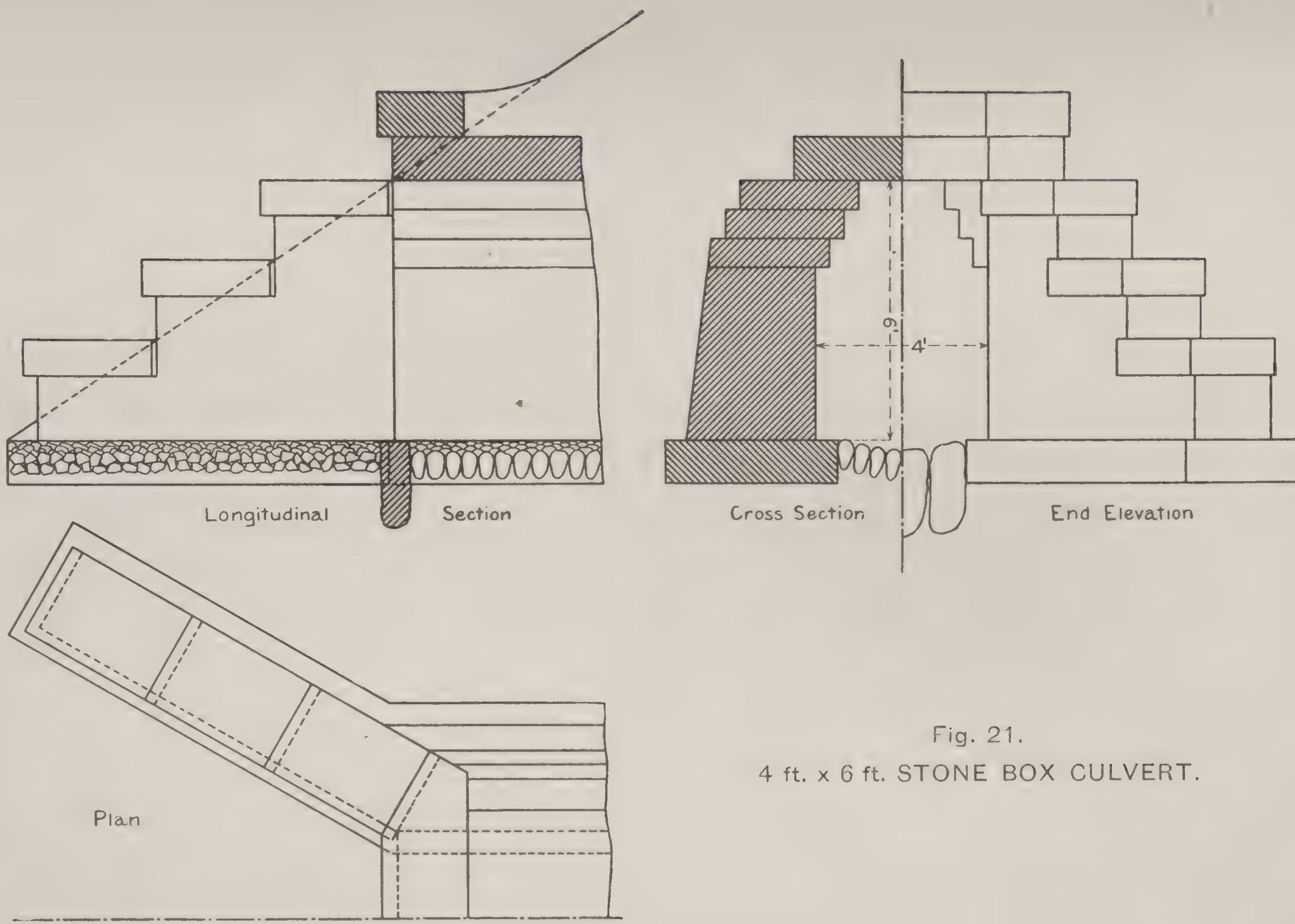


Fig. 21.
4 ft. x 6 ft. STONE BOX CULVERT.

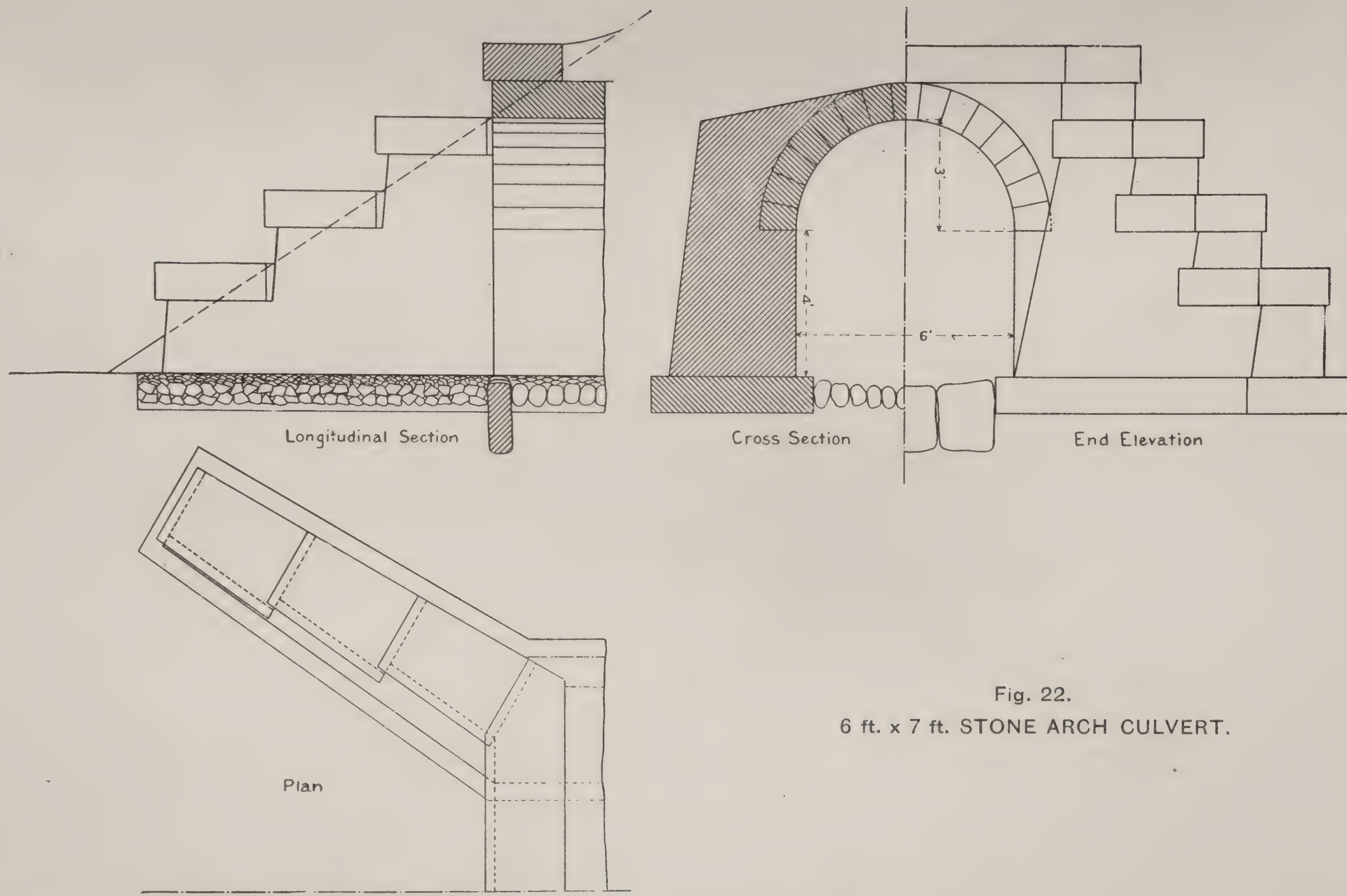


Fig. 22.
6 ft. x 7 ft. STONE ARCH CULVERT.

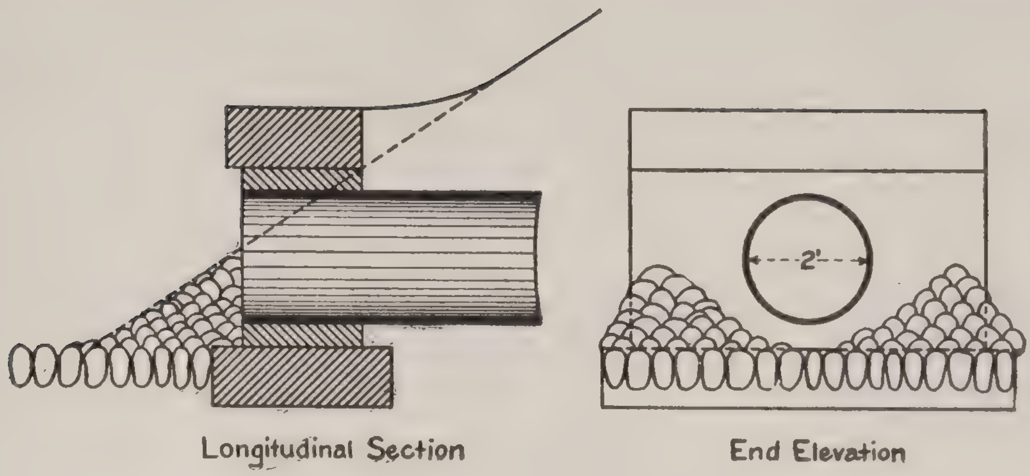


Fig. 23. PIPE CULVERT.

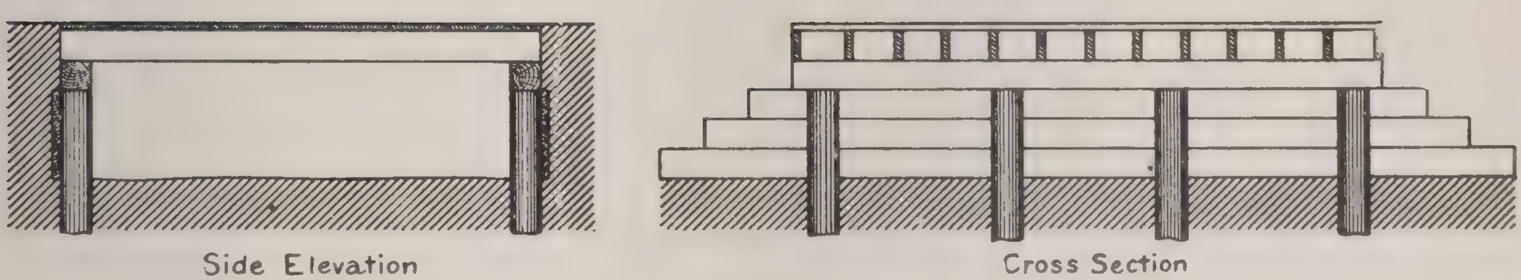


Fig. 24. PILE BRIDGE.

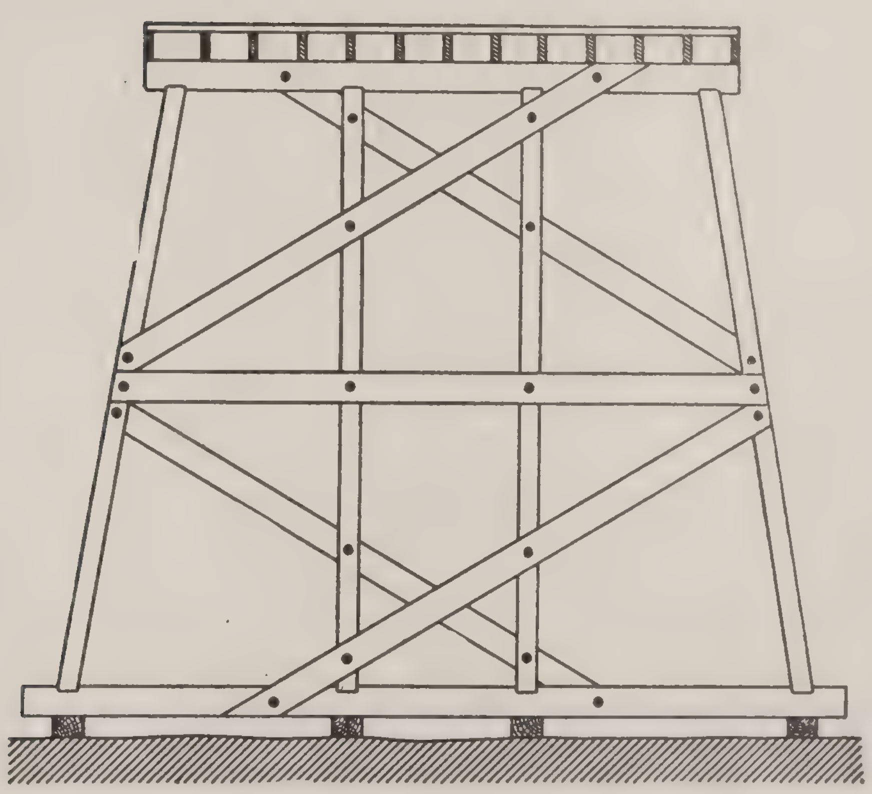


Fig. 26. TRESTLE.

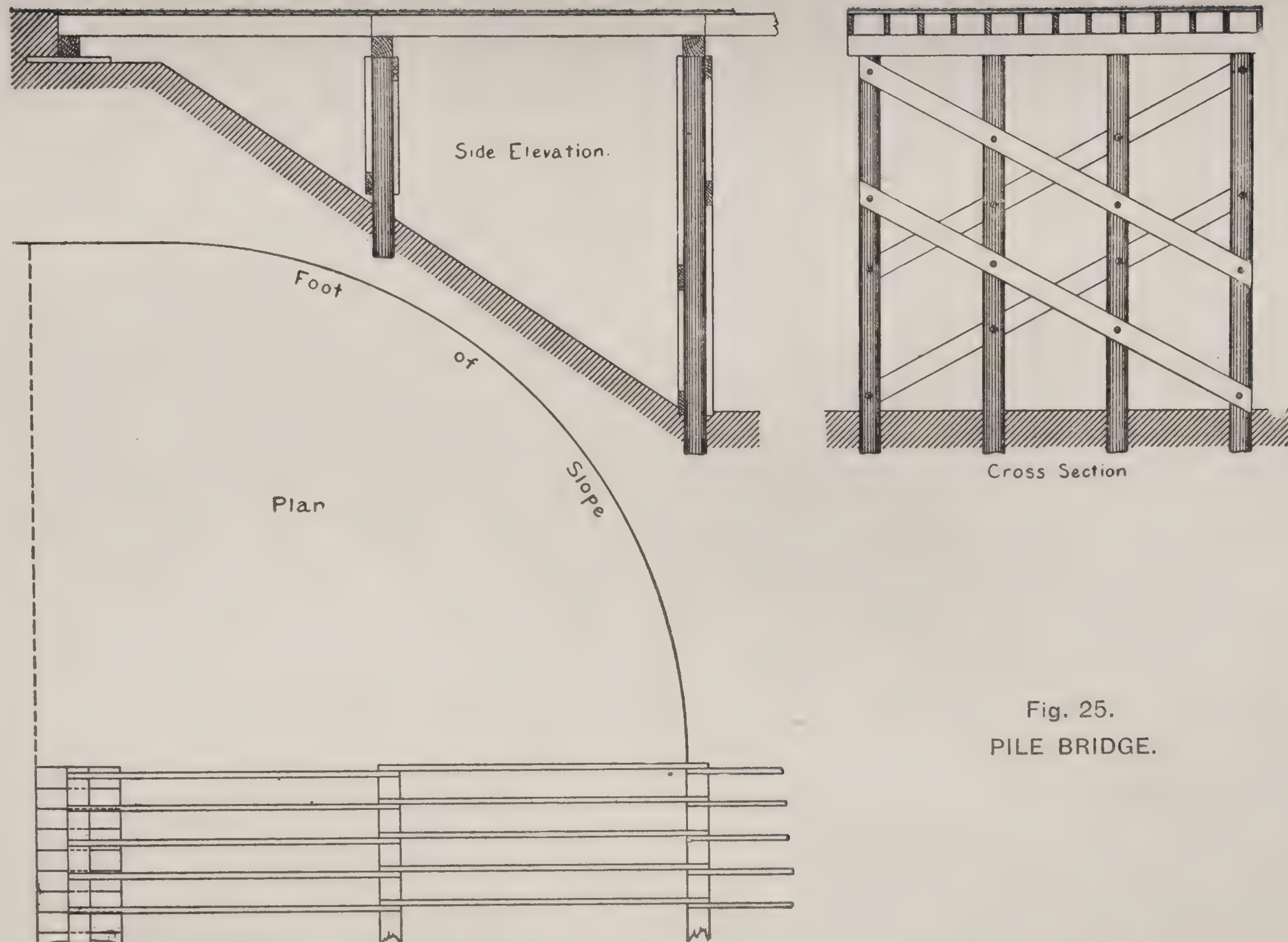


Fig. 25.
PILE BRIDGE.

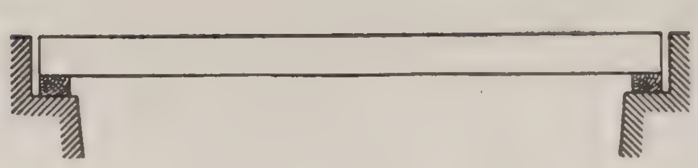
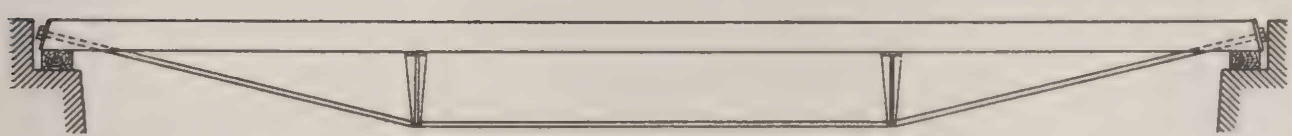


Fig. 27.

Fig. 28.



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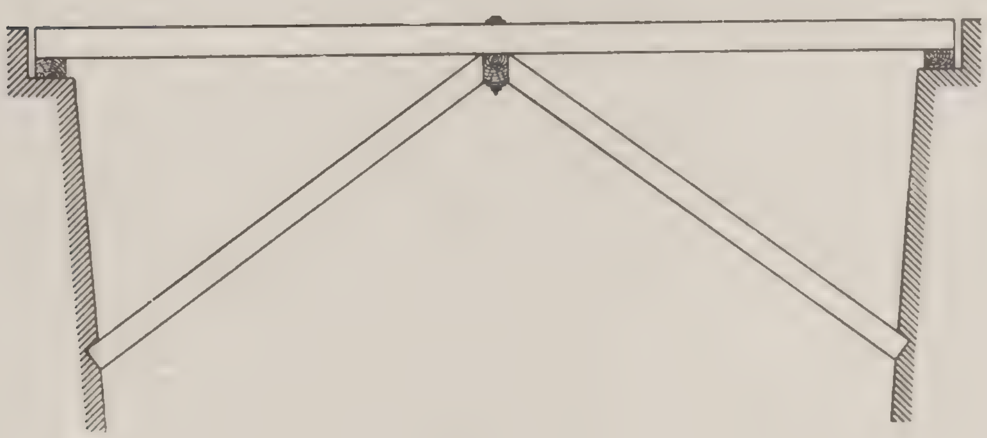
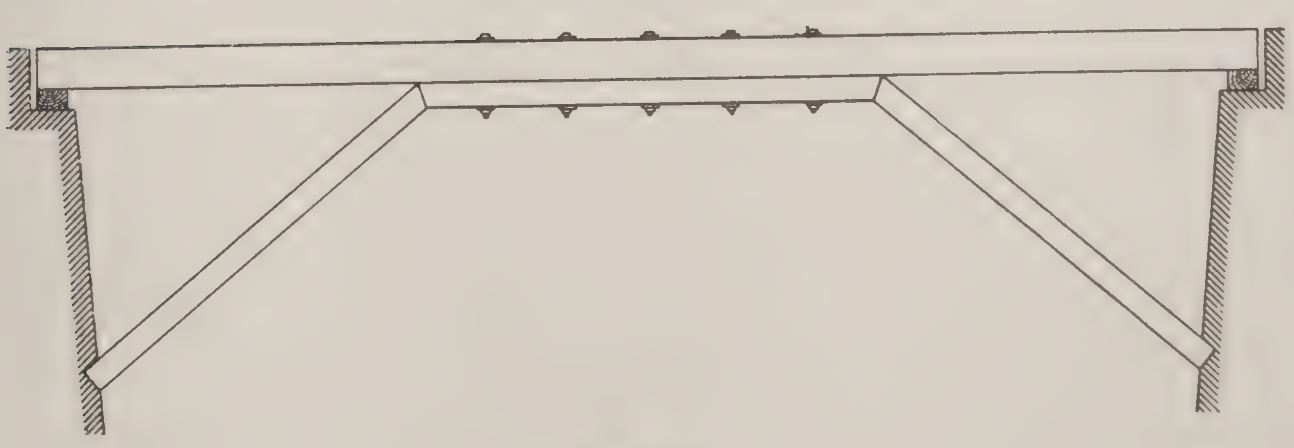


Fig. 30.



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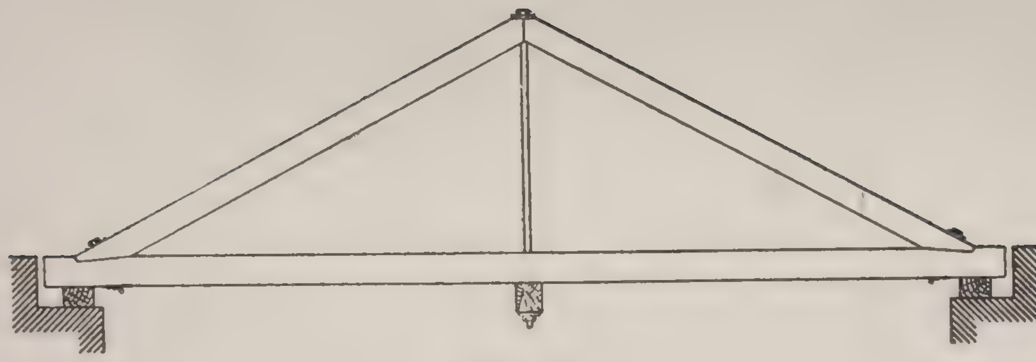


Fig. 32.

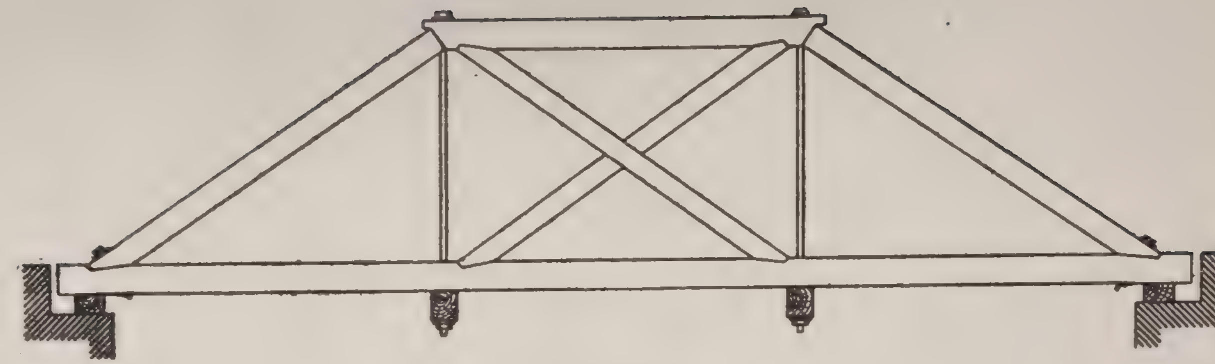


Fig. 33.

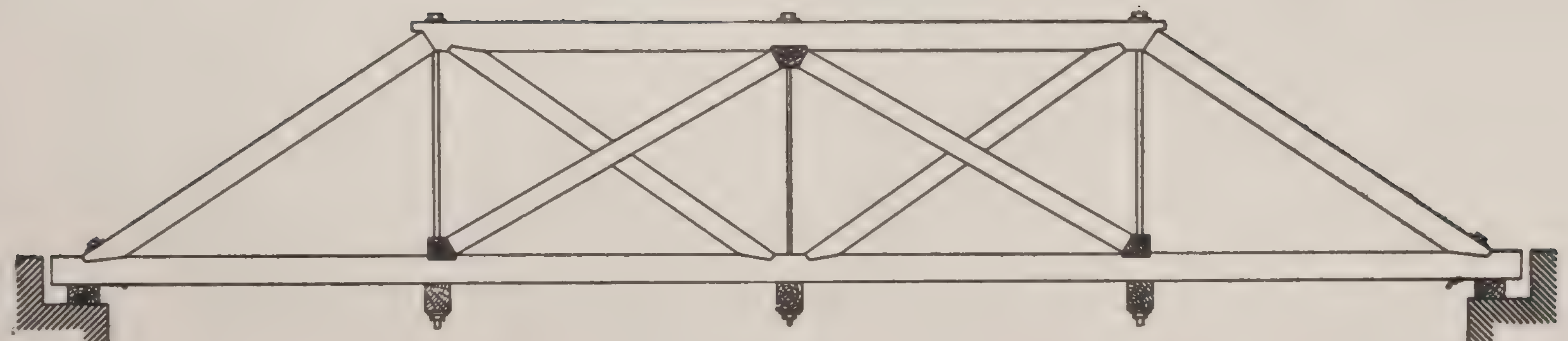


Fig 34.

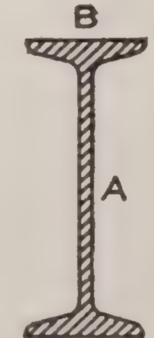


Fig. 35.

Fig. 36.

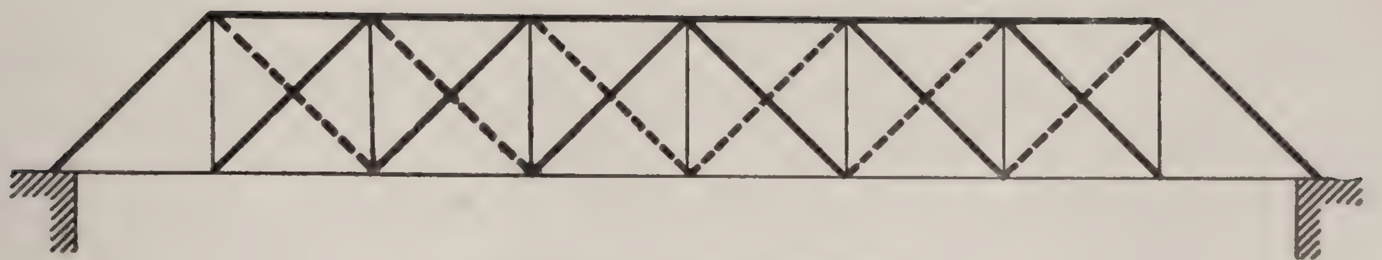


Fig. 37. HOWE TRUSS.

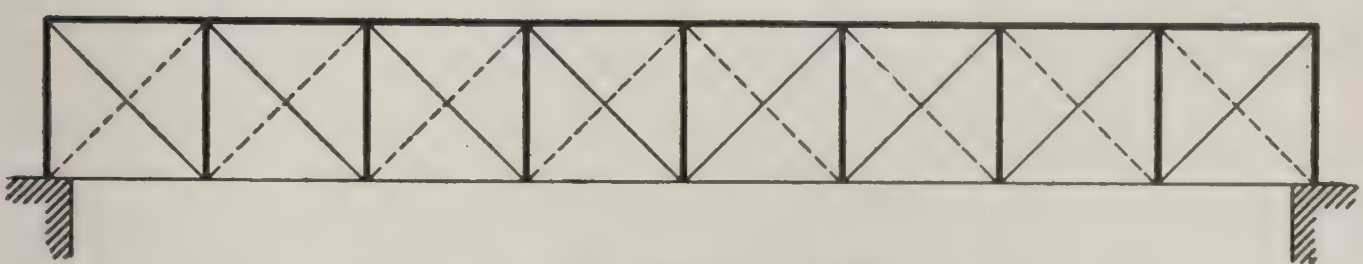


Fig. 38. PRATT TRUSS.

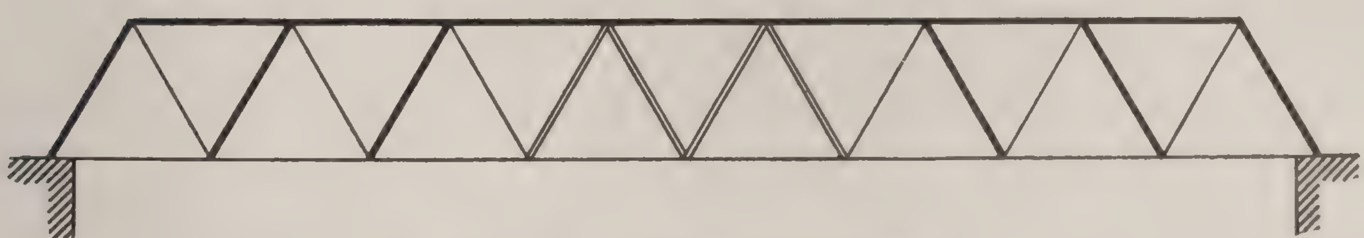


Fig. 39. WARREN TRUSS.

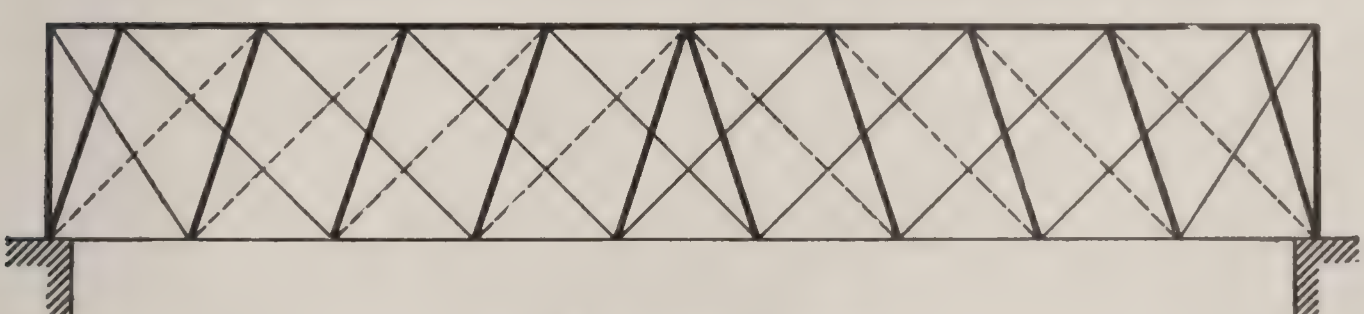


Fig. 40. POST TRUSS.

Fig. 41. FINK TRUSS.

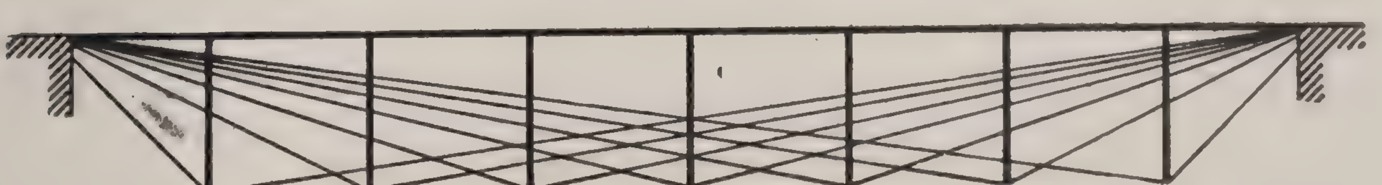


Fig. 42. BOLLMAN TRUSS.

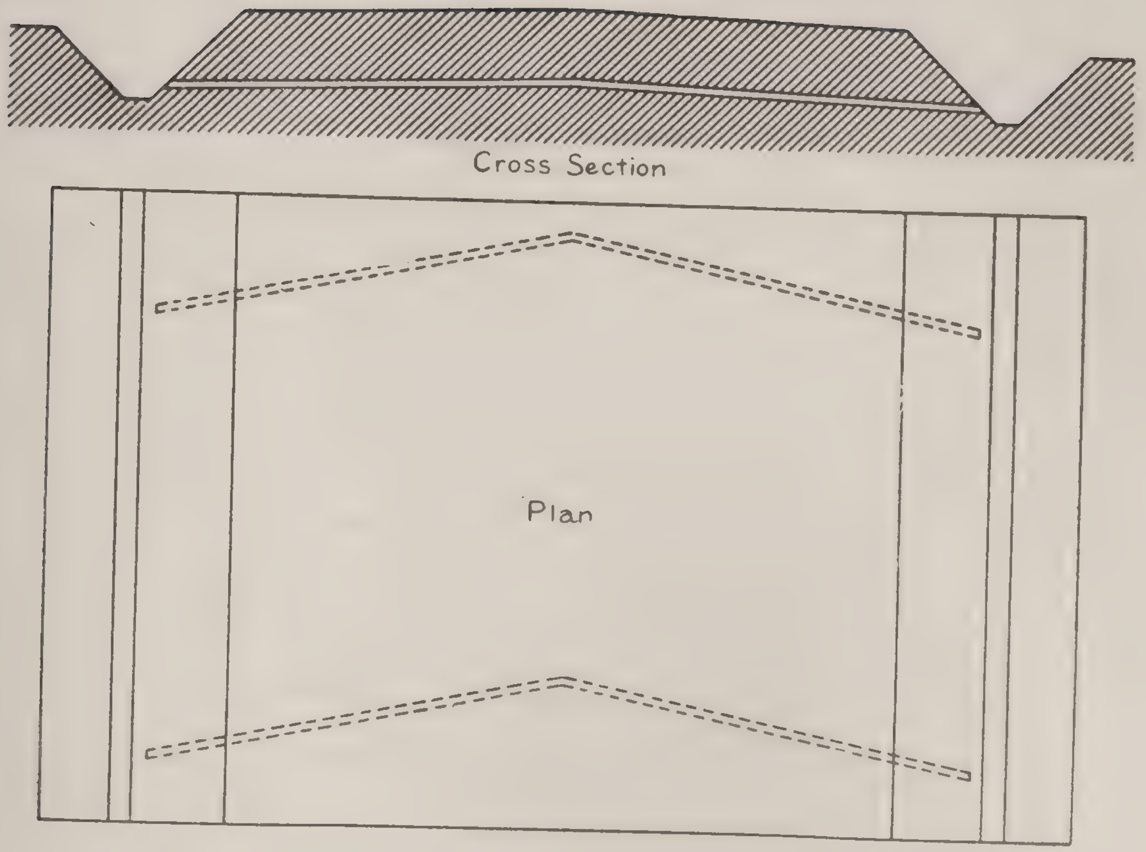
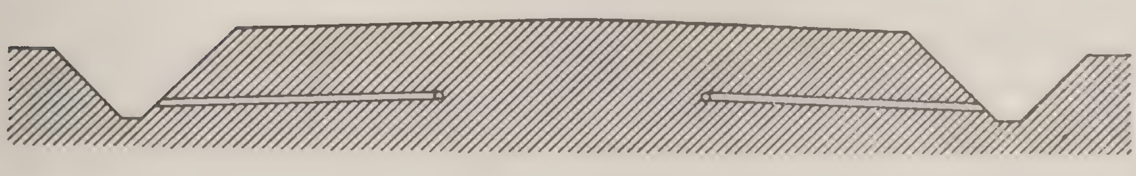


Fig. 43.



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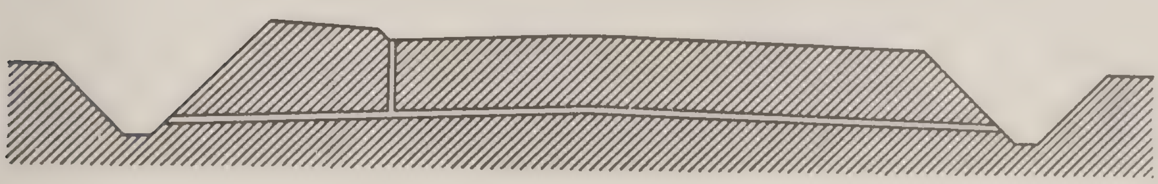


Fig. 45.

Fig. 46.

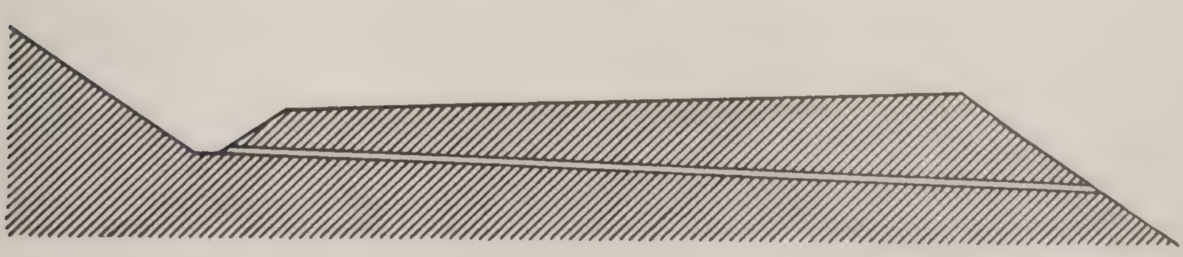
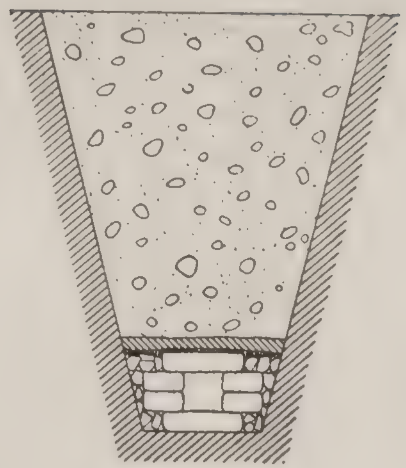


Fig. 47.

Fig. 48.



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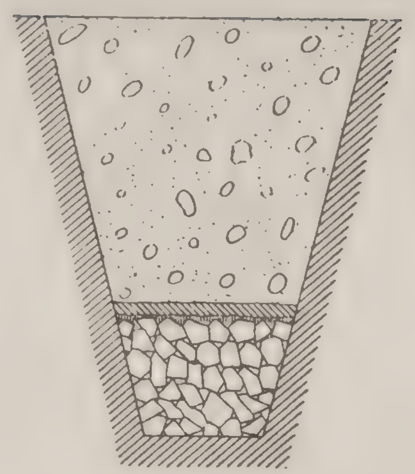

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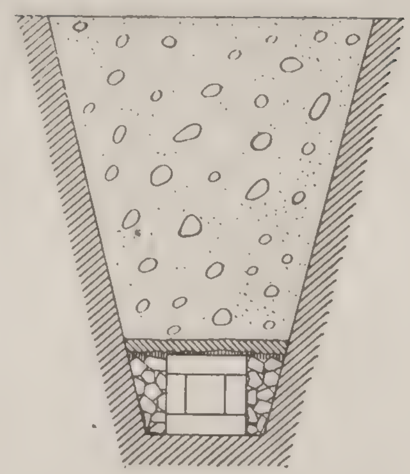

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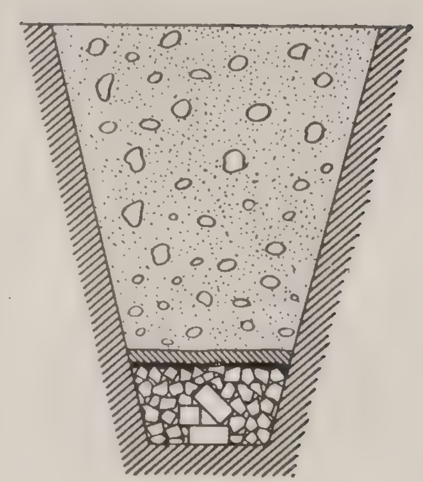


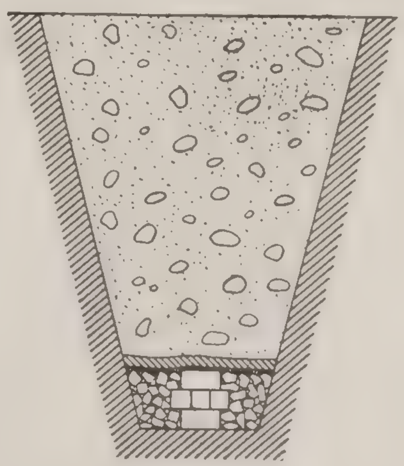
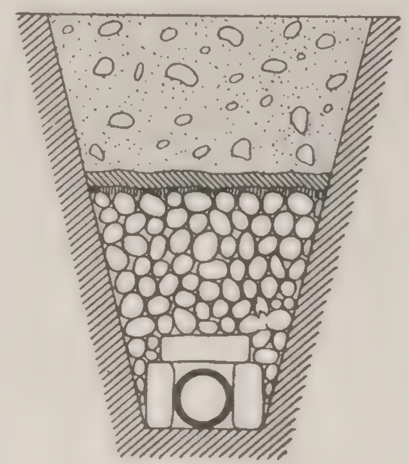


Fig. 52.

Fig. 53.



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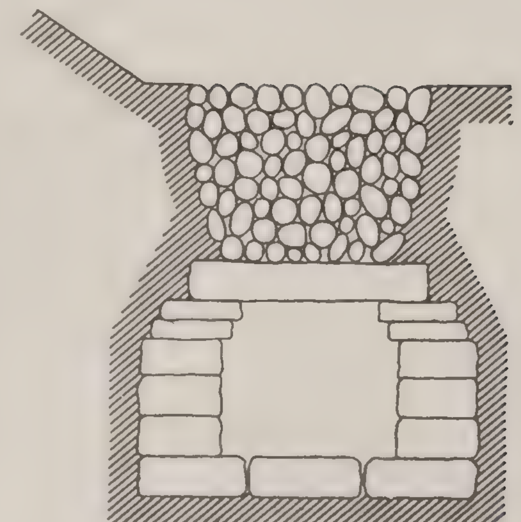


Fig. 54a.

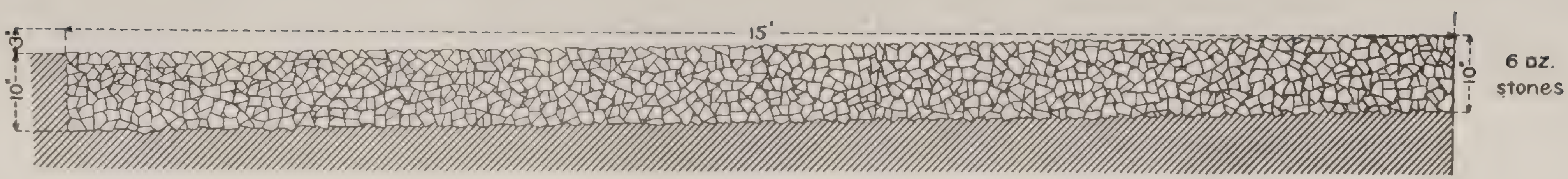


Fig. 55. MACADAM ROAD.

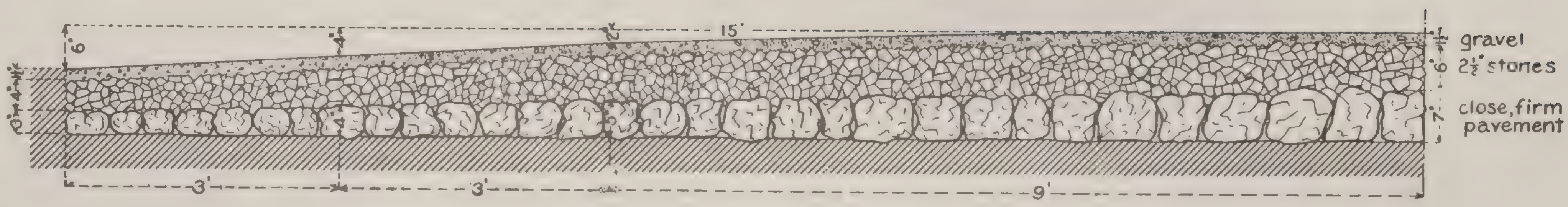


Fig. 56. TELFORD ROAD.

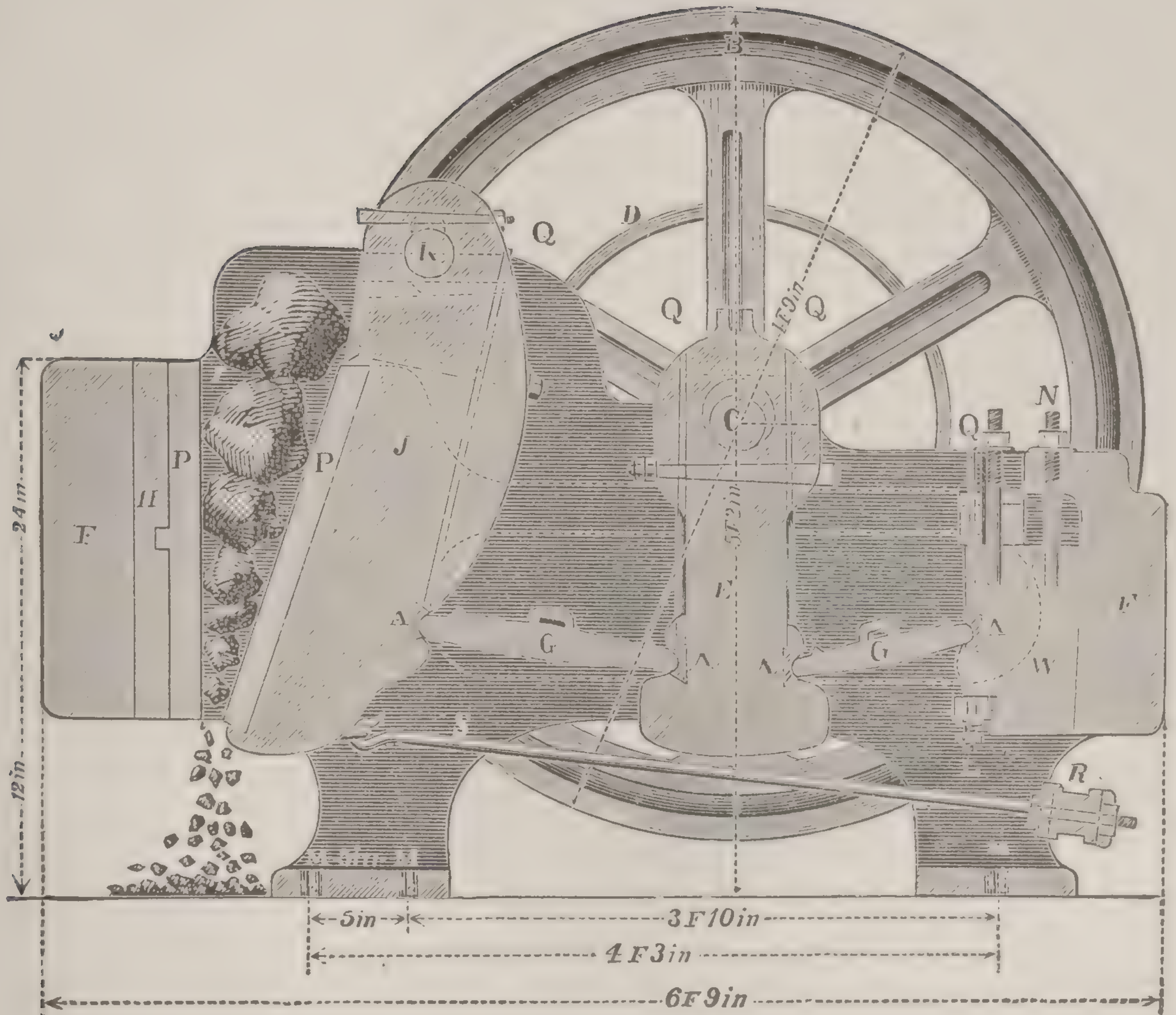


Fig. 57.

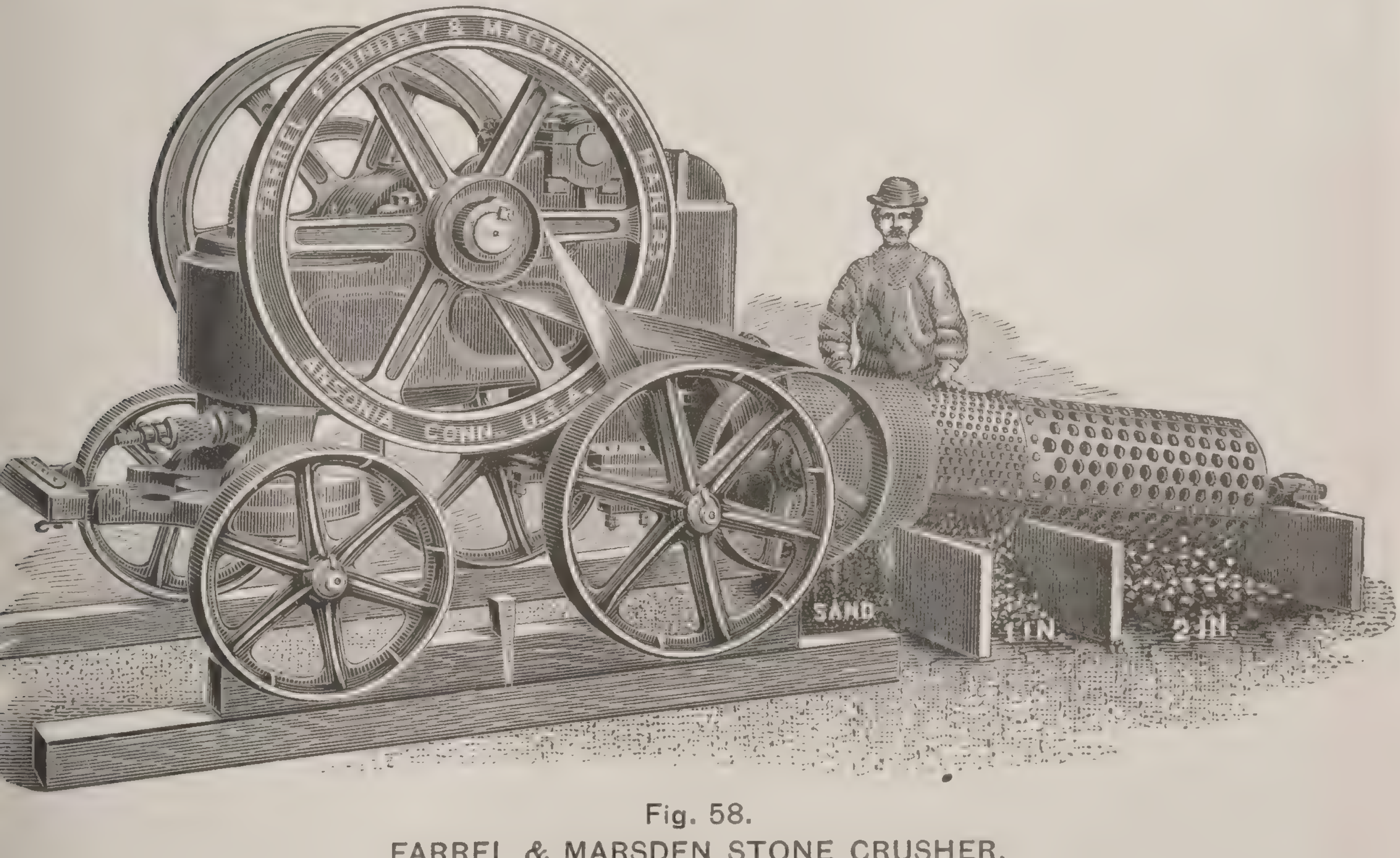


Fig. 58.

FARREL & MARSDEN STONE CRUSHER.

(Blake Style.)

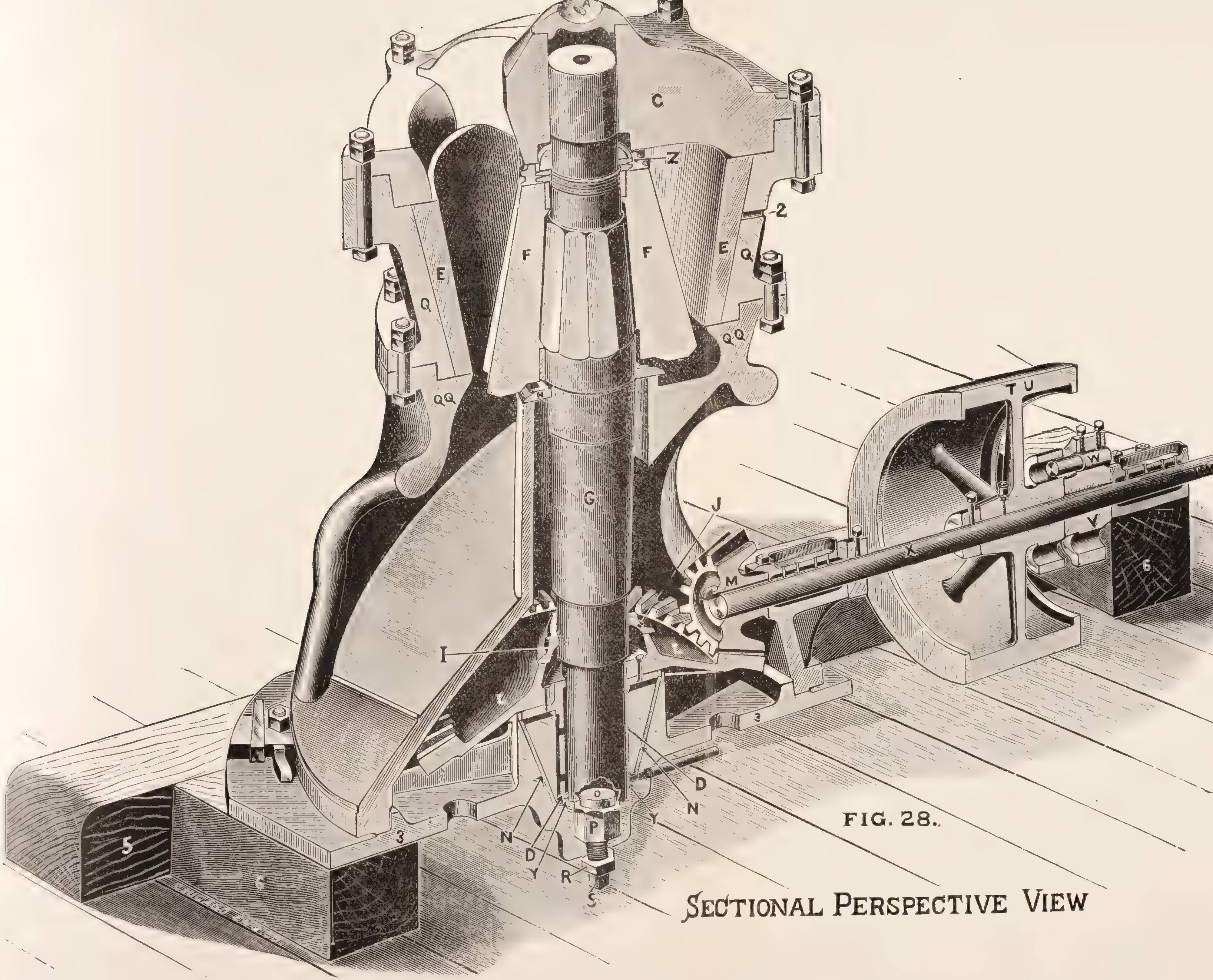
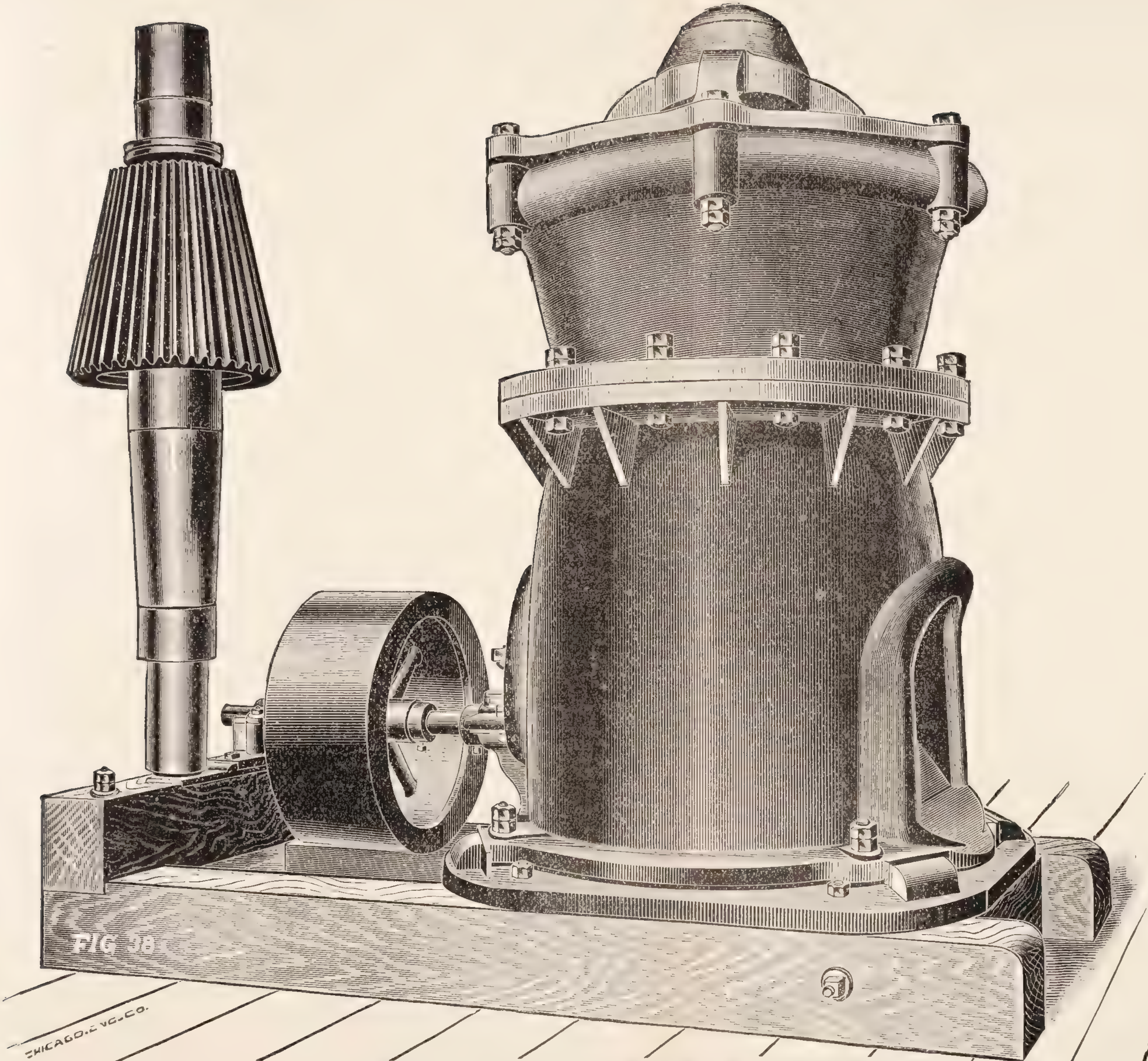


FIG. 28.

SECTIONAL PERSPECTIVE VIEW

Fig. 59. GATES ROCK AND ORE BREAKER.



CAPACITIES IN TONS OF 2,000 POUNDS.

SIZE 0— 2 to 4	Tons per hour.	SIZE 4— 15 to 30	Tons per hour.
" 1— 4 to 8	Tons " "	" 5— 25 to 40	Tons " "
" 2— 6 to 12	Tons " "	" 6— 30 to 60	Tons " "
" 3—10 to 20	Tons " "	" 7— 40 to 75	Tons " "
		" 8—100 to 150	Tons " "

Passing 2 ½ inch ring, according to character and hardness of material.

Fig. 60. GATES ROCK AND ORE BREAKER.

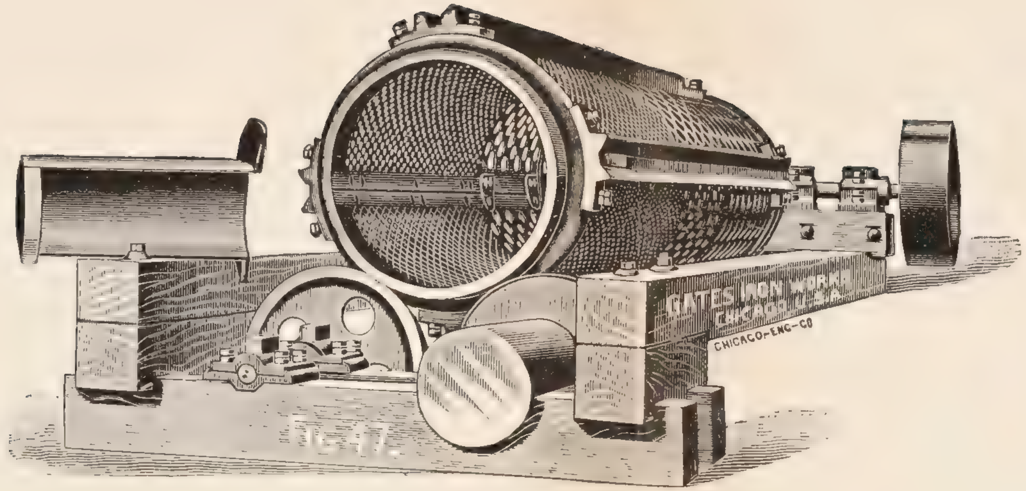
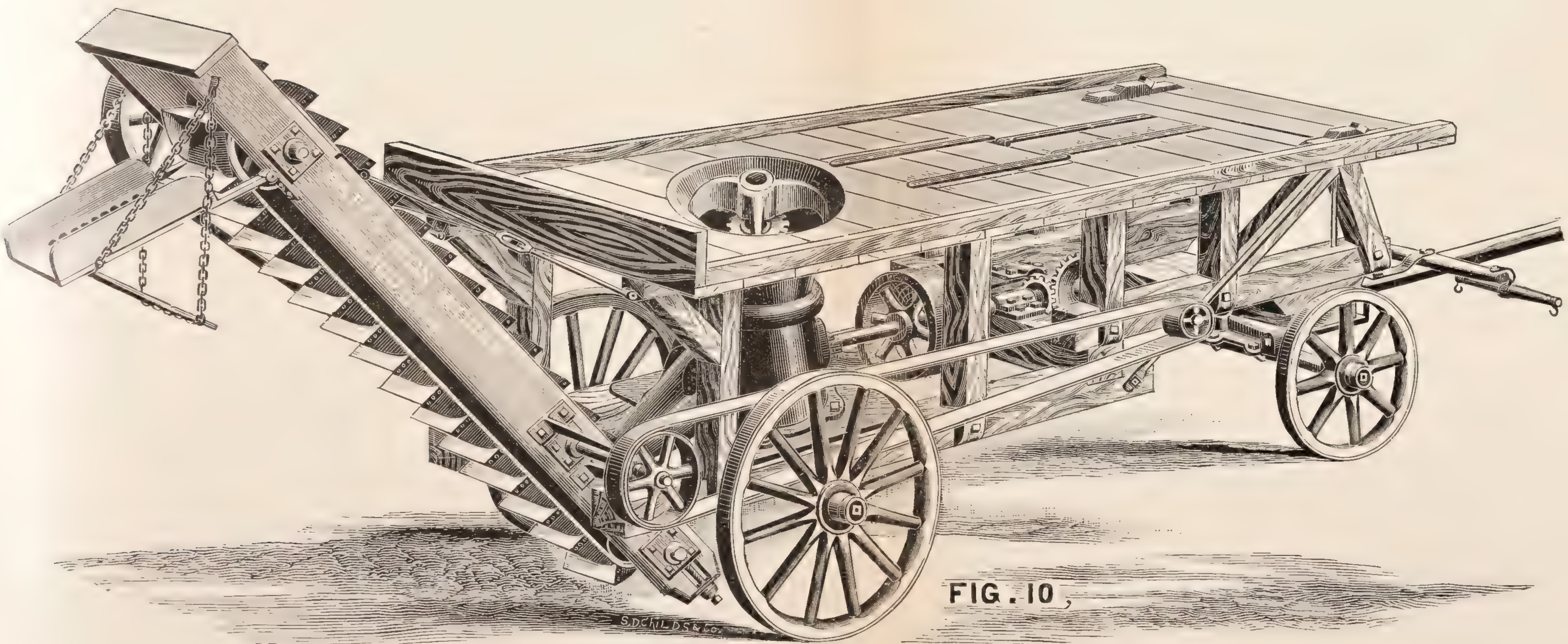


Fig. 62. REVOLVING SCREEN.



PORTABLE BREAKER

Fig. 61.

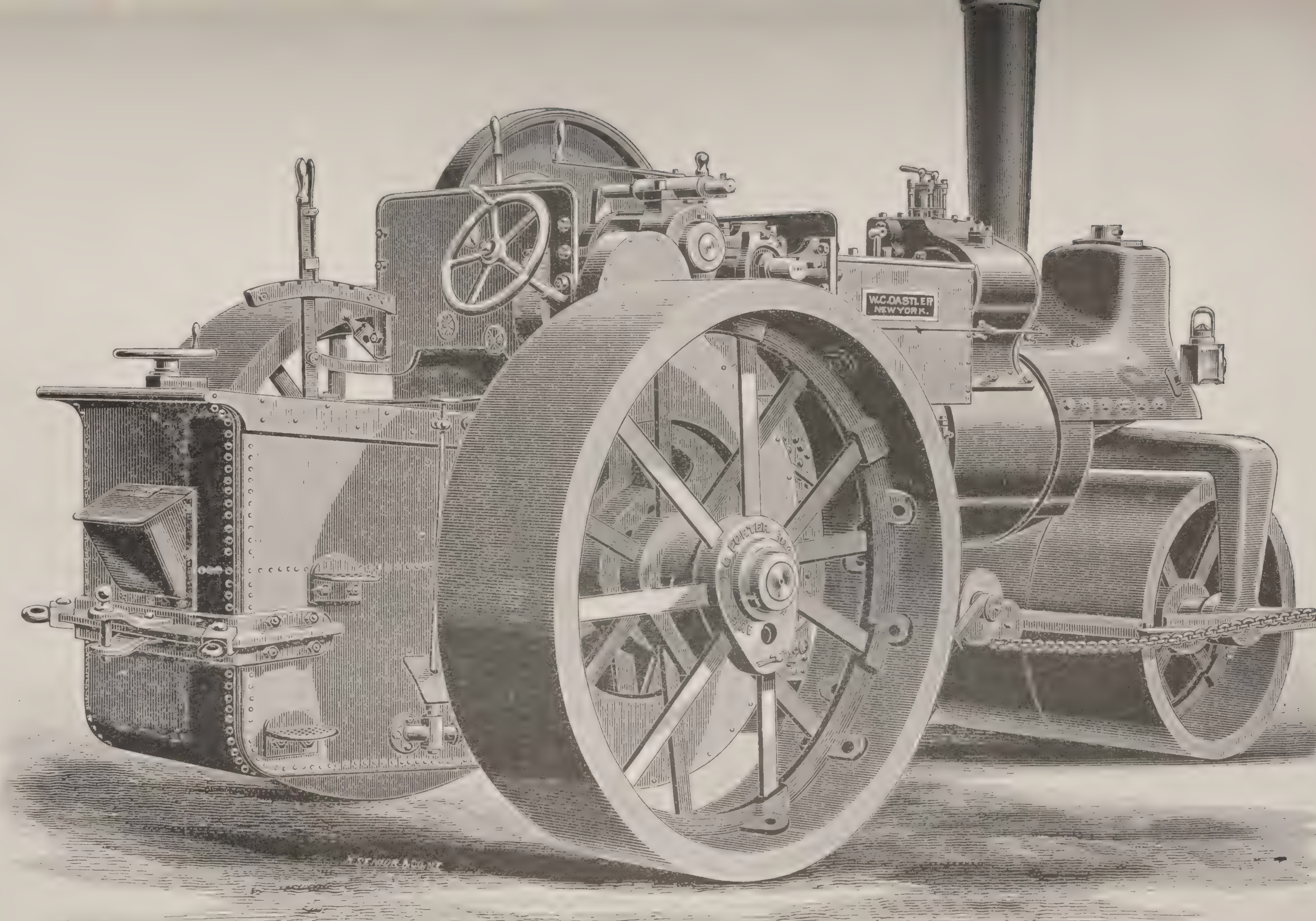


Fig. 63. AVELING & PORTER STEAM ROLLER.

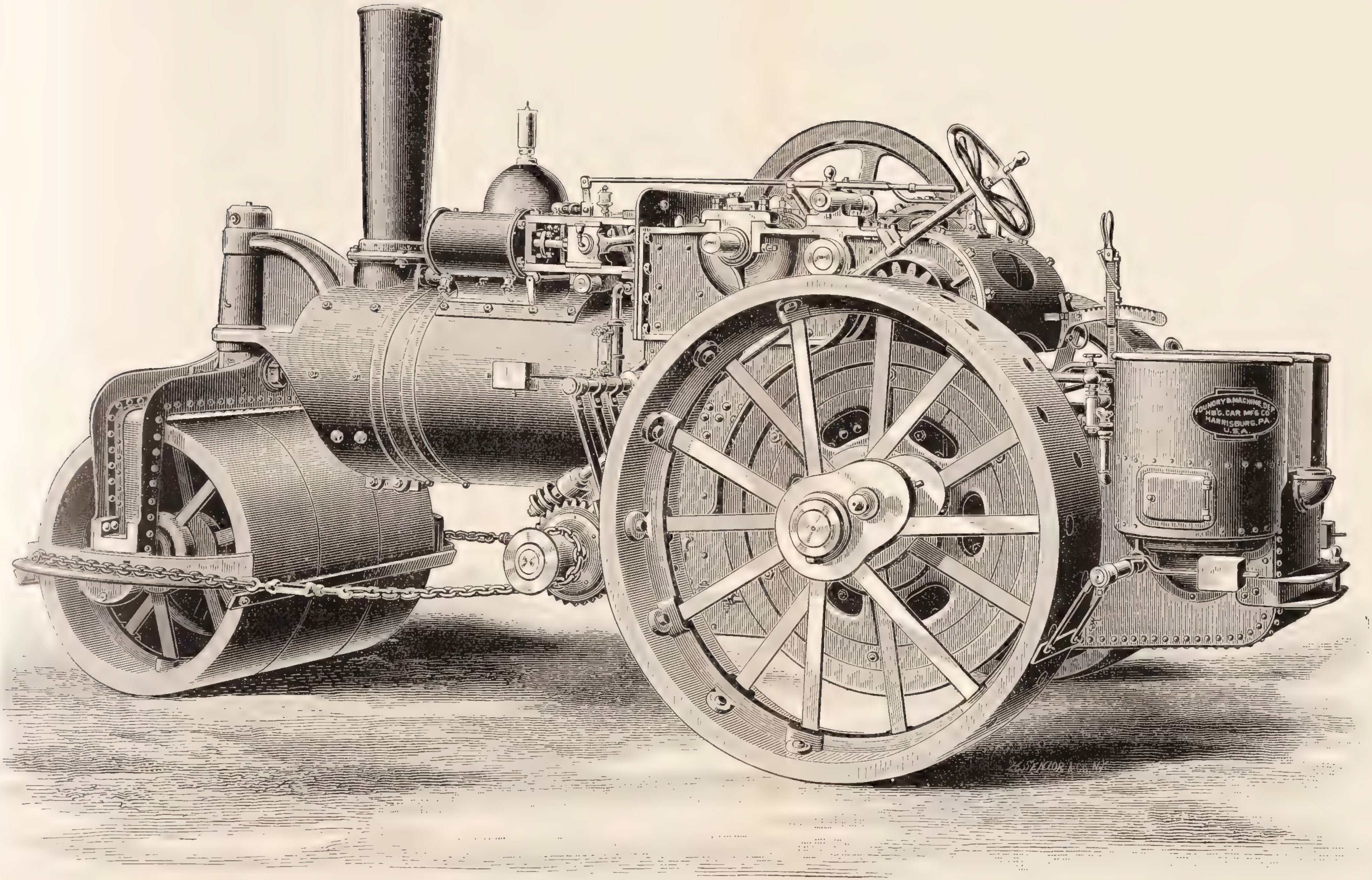


Fig. 64. HARRISBURG DOUBLE-ENGINE STEAM ROAD ROLLER.

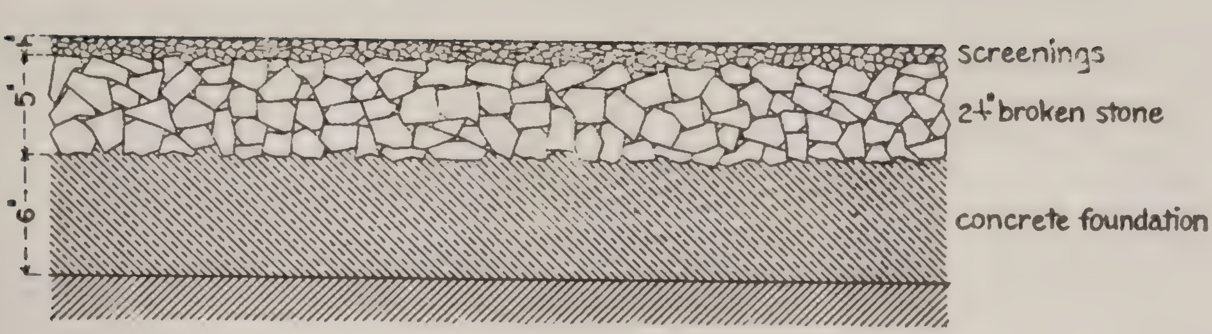


Fig. 66.

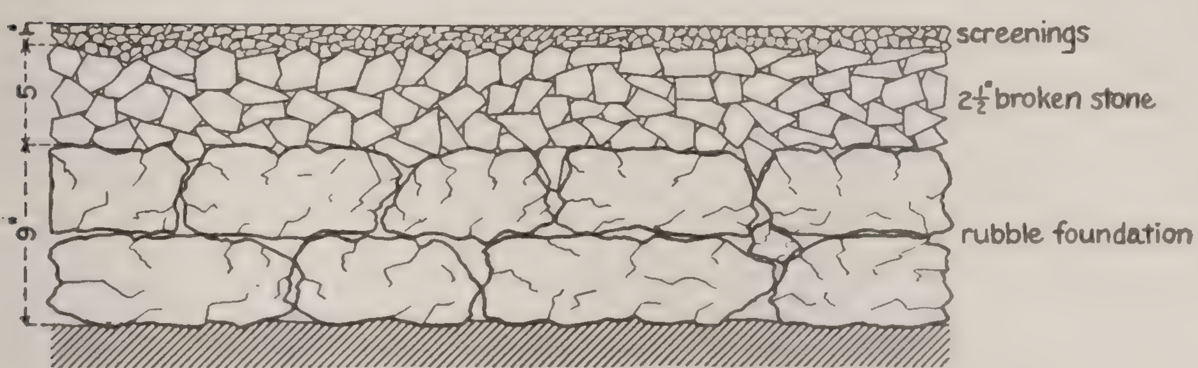


Fig. 67.

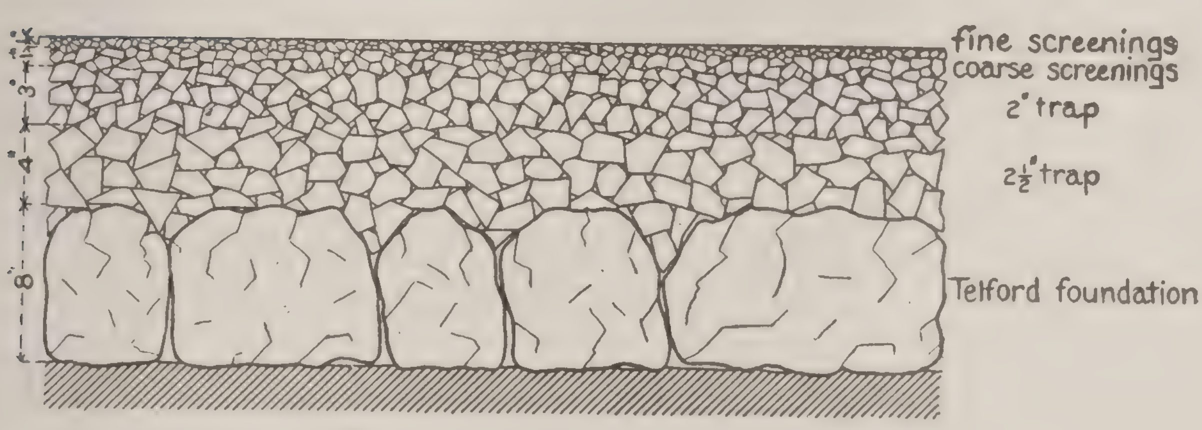


Fig. 68. 5th AVENUE, NEW YORK.

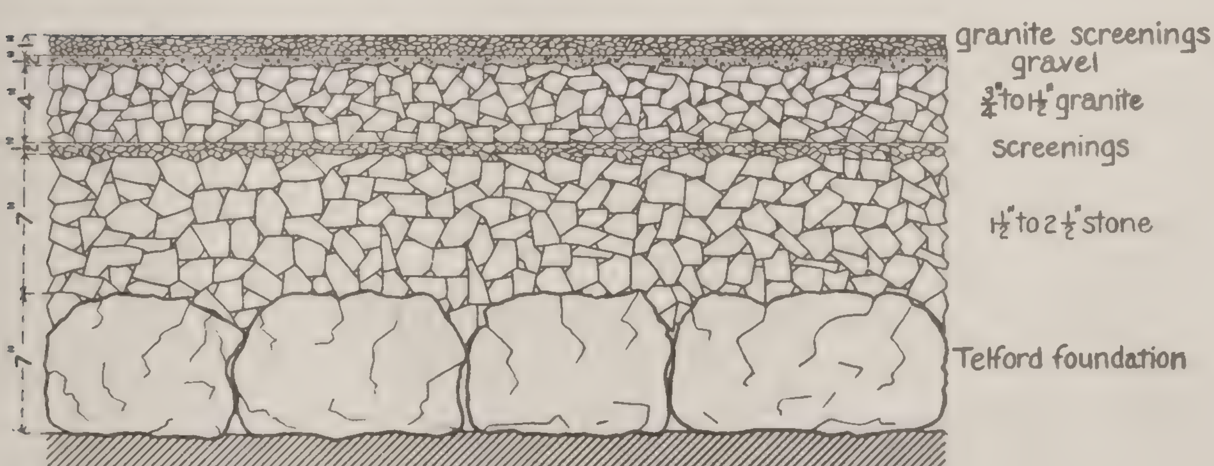


Fig. 69. CHICAGO (Old).

BROKEN STONE ROADS.

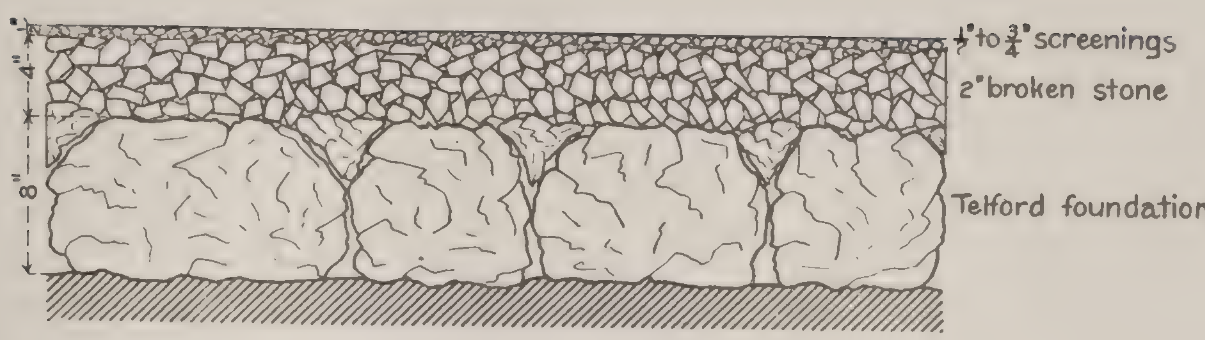


Fig. 70.

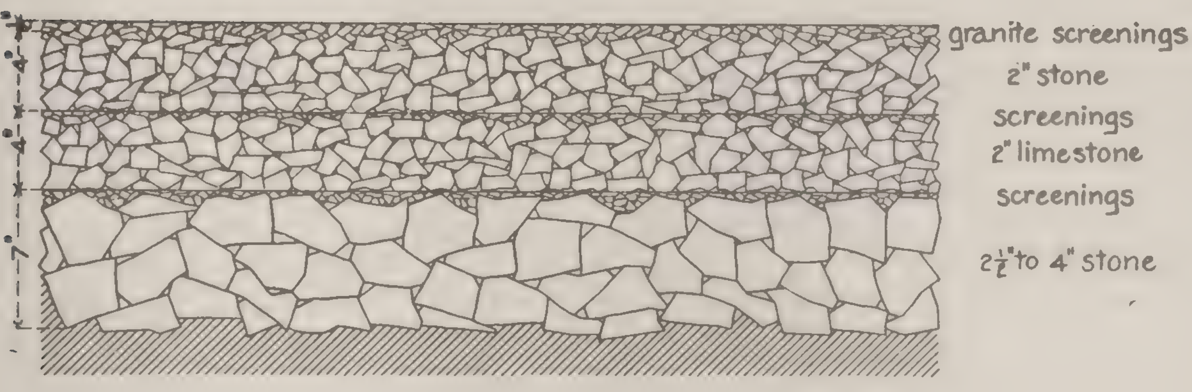


Fig. 71. CHICAGO (New).

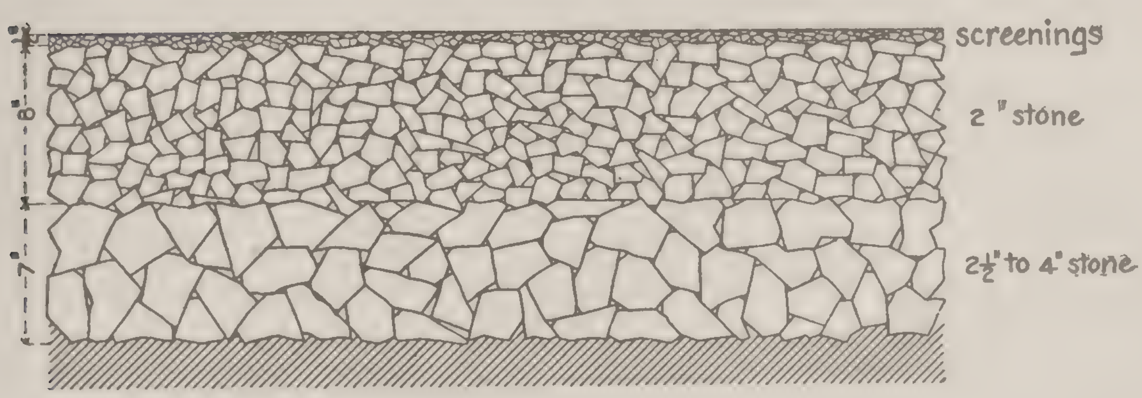


Fig. 72.

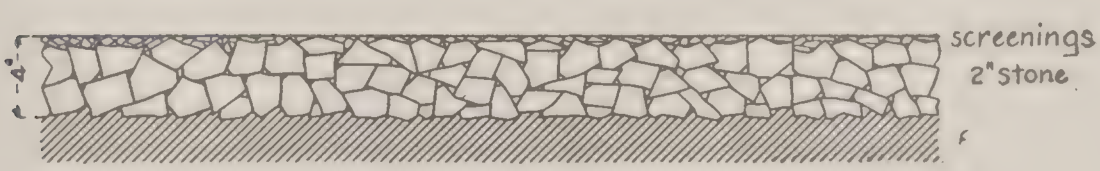


Fig. 73. BRIDGEPORT, CONN.

BROKEN STONE ROADS.

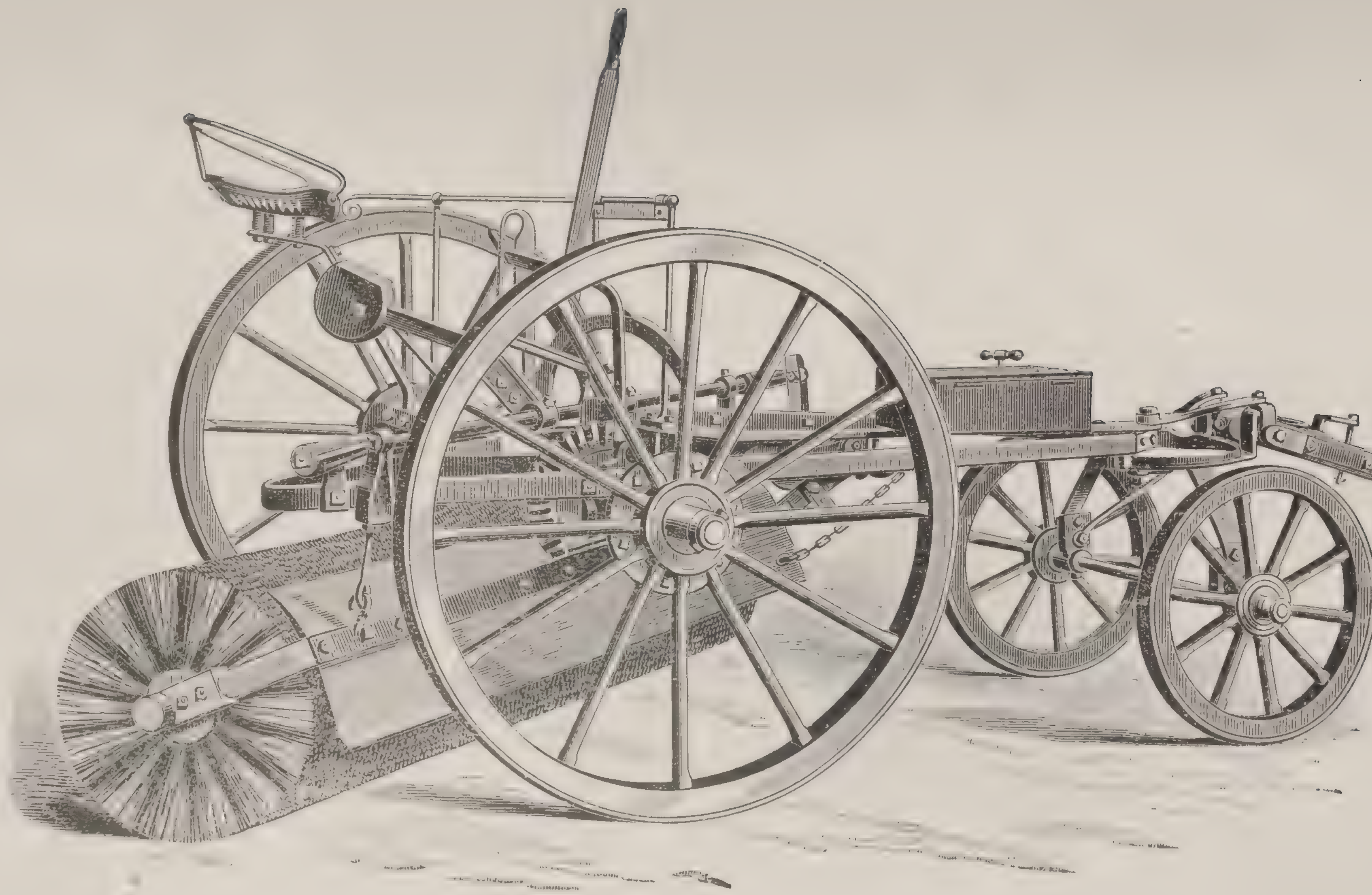


Fig. 74. "BARNARD-CASTLE" STREET SWEEPER.

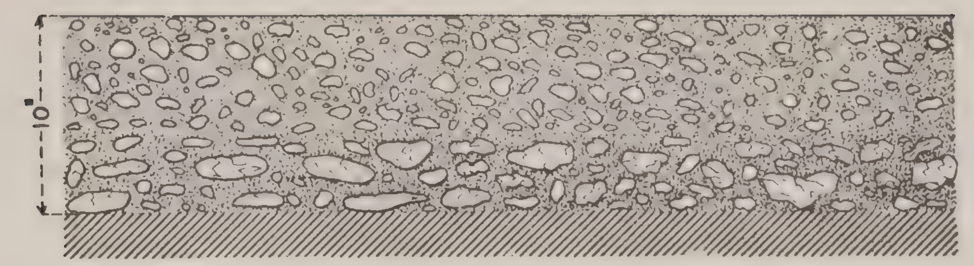


Fig. 76. ORDINARY GRAVEL ROAD.

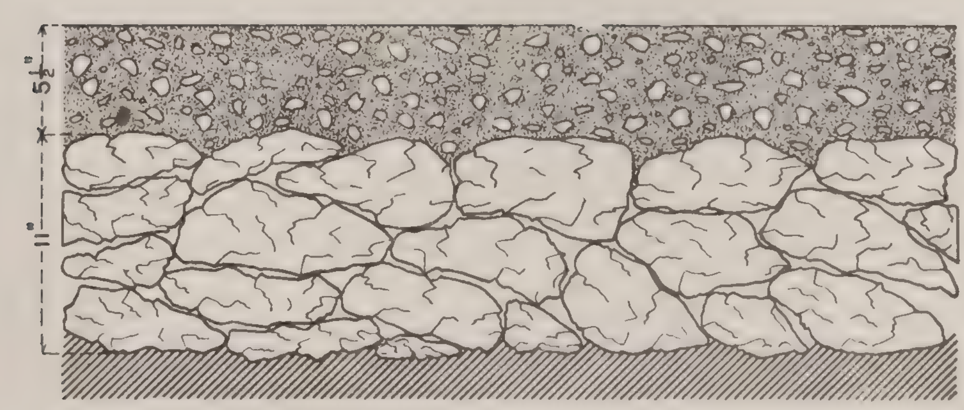


Fig. 77. GRAVEL ROAD, CENTRAL PARK, NEW YORK.

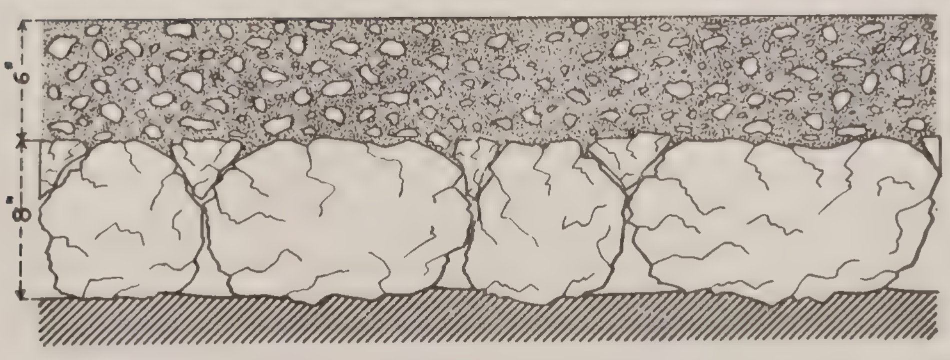


Fig. 78. GRAVEL ROAD, CENTRAL PARK, NEW YORK.

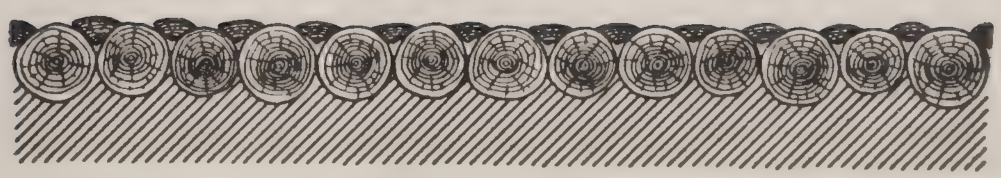


Fig. 79. CORDUROY ROAD.

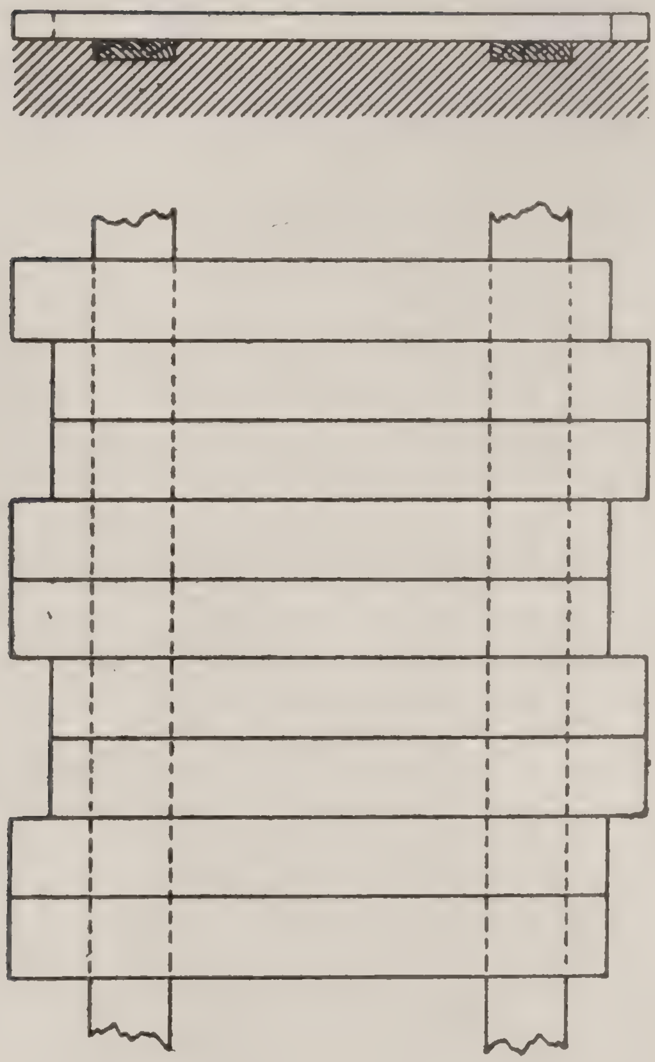


Fig. 80. PLANK ROAD.

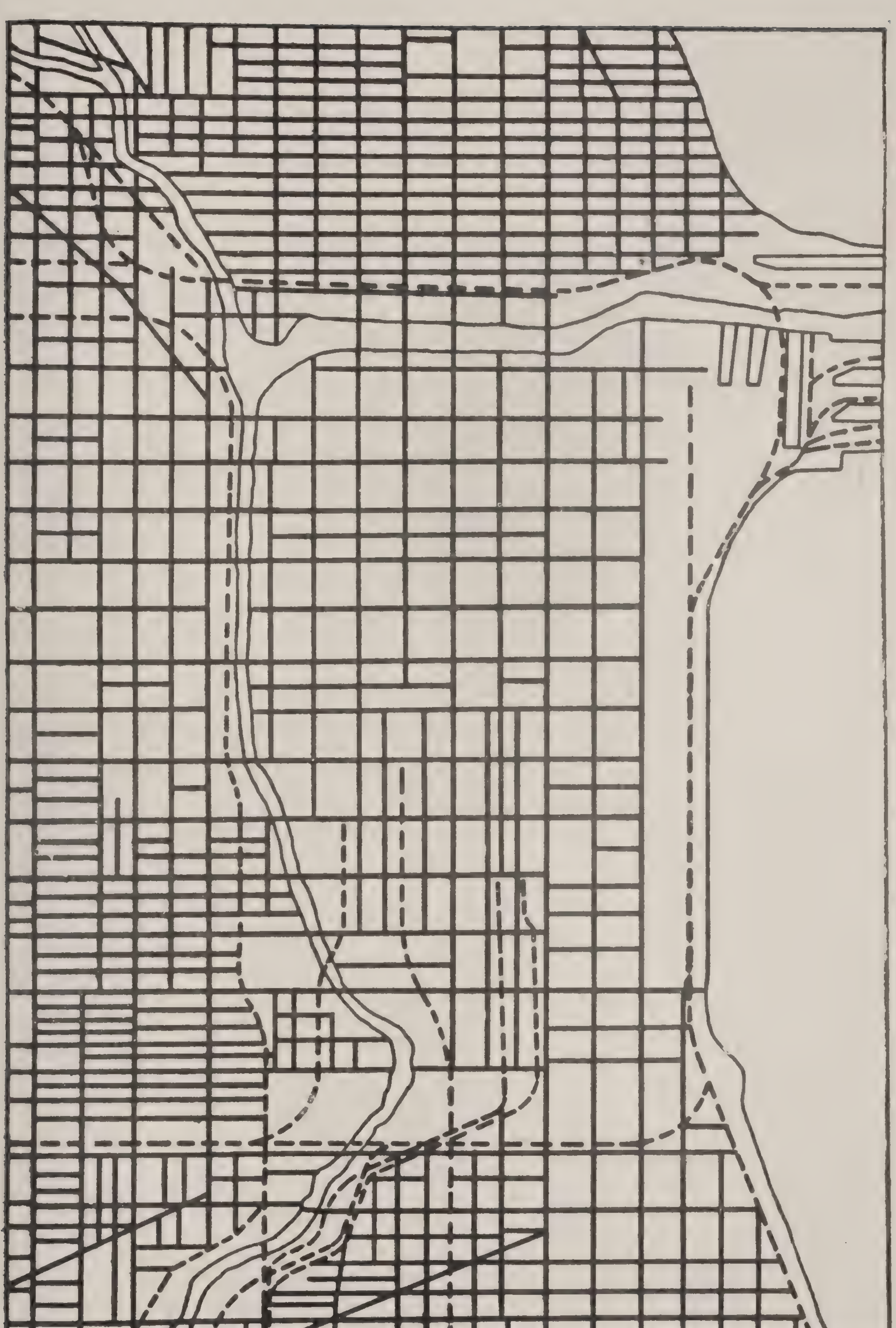


Fig. 81. MAP OF CHICAGO, ILL.

Fig. 82. MAP OF BOSTON, MASS.

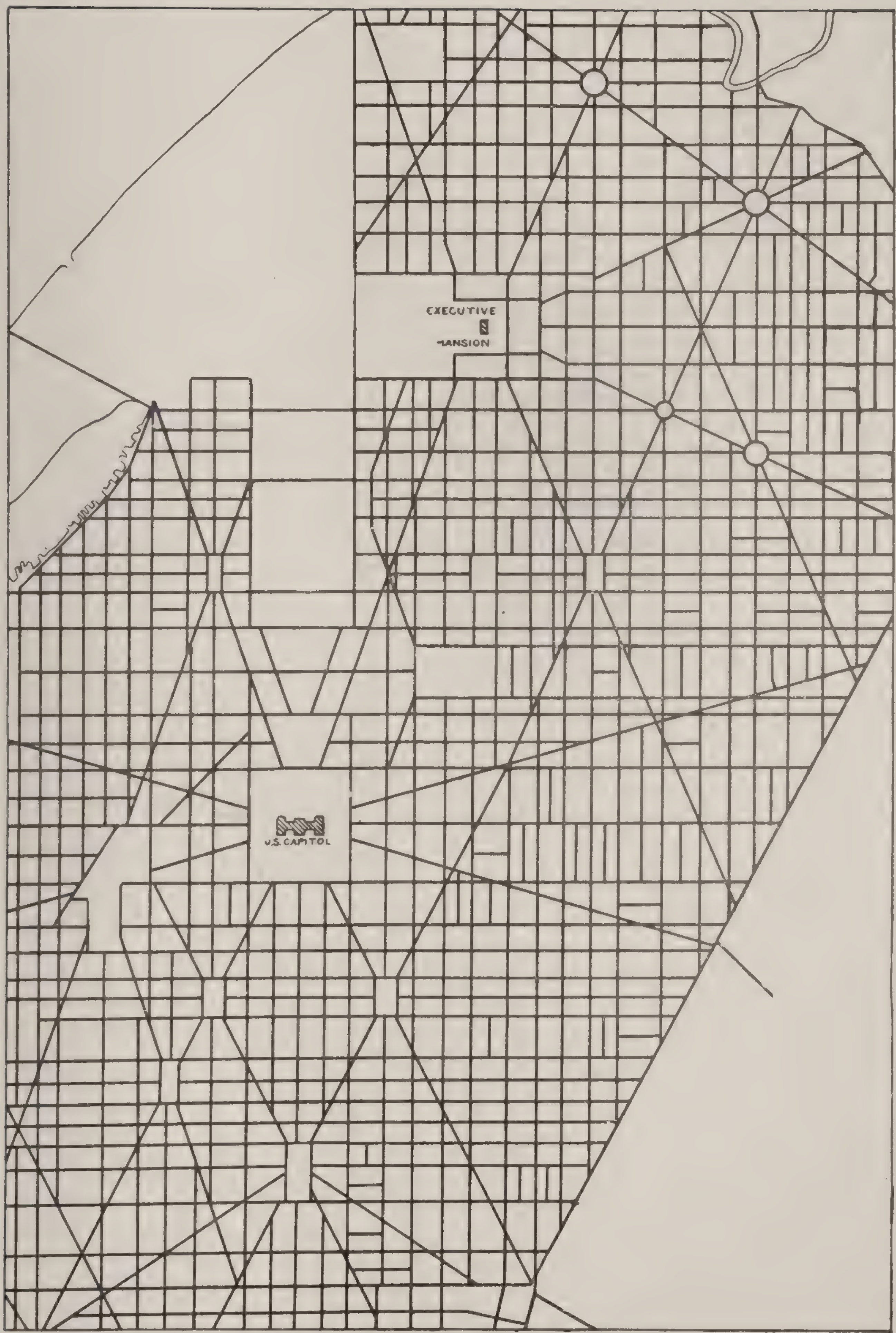


Fig. 83. MAP OF WASHINGTON, D. C.

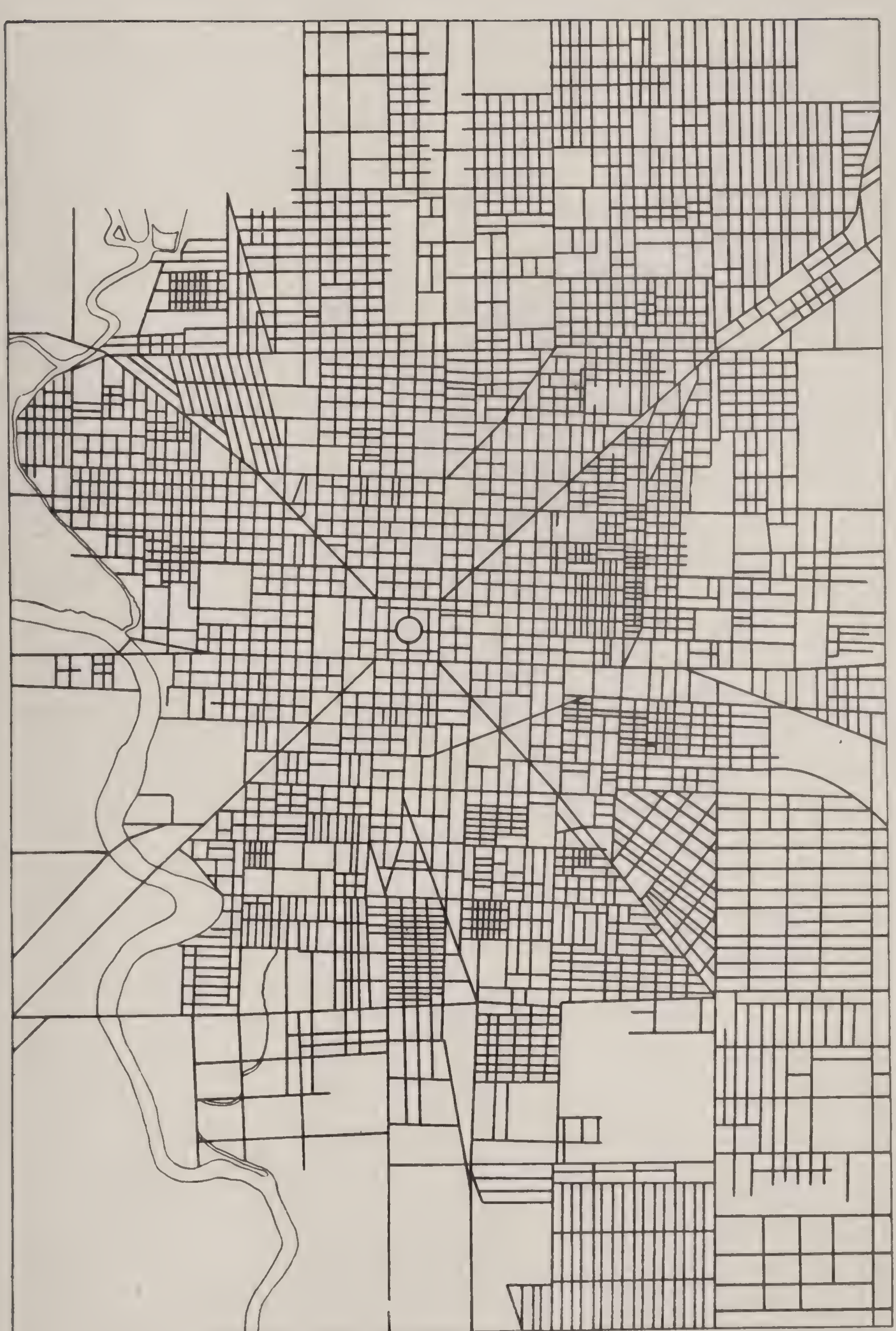


Fig. 84. MAP OF INDIANAPOLIS, IND.

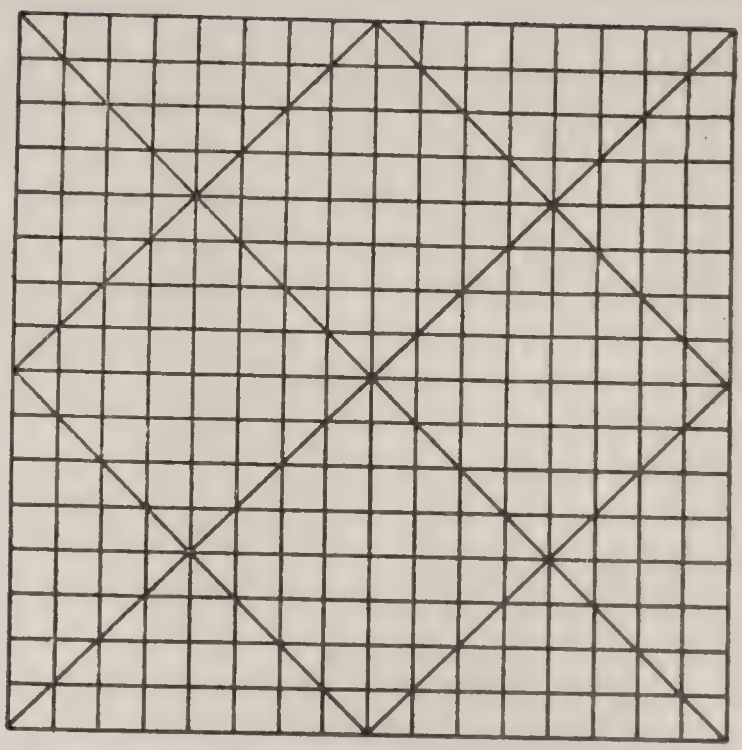


Fig. 85.

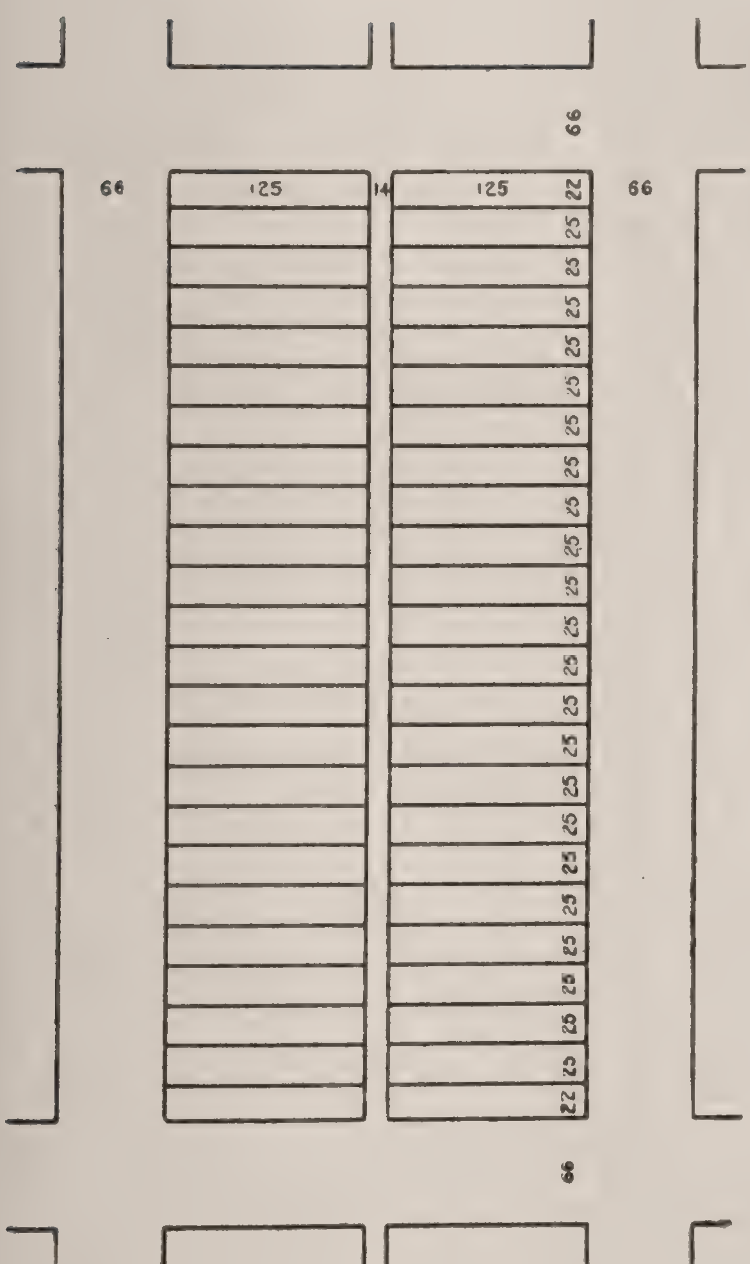


Fig. 86.

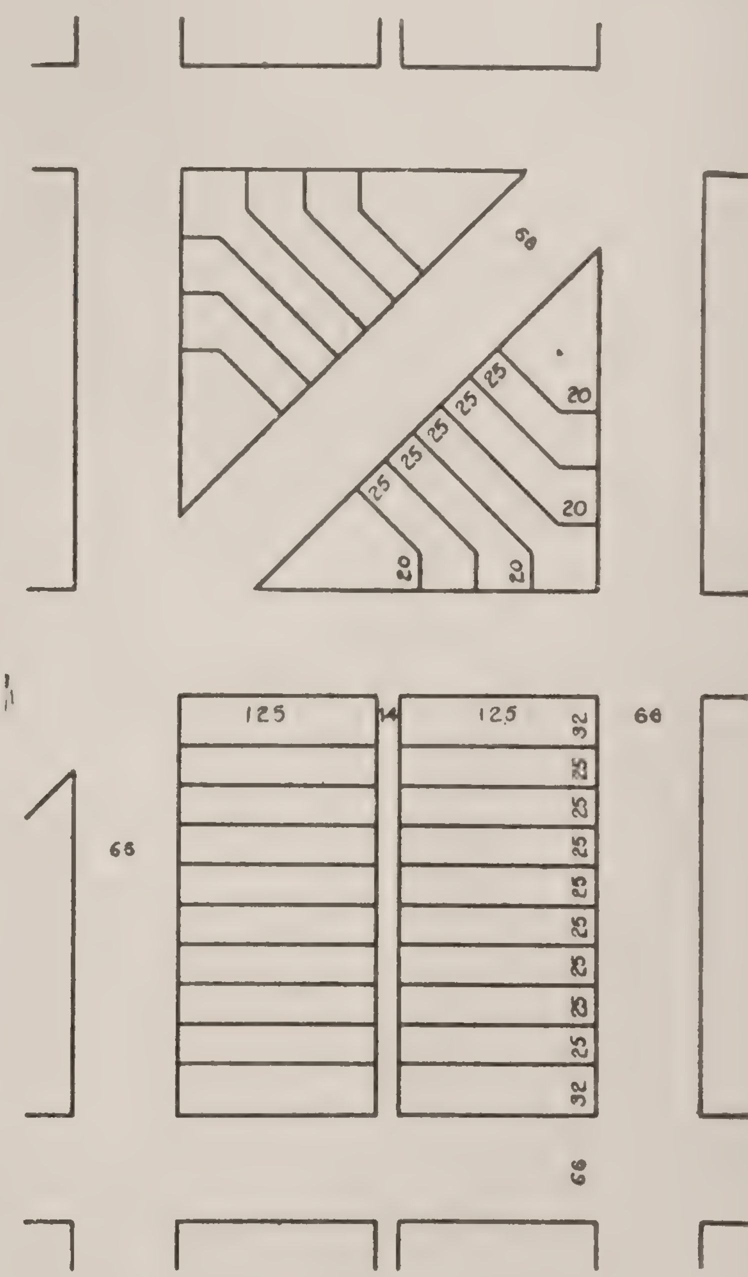


Fig. 87.

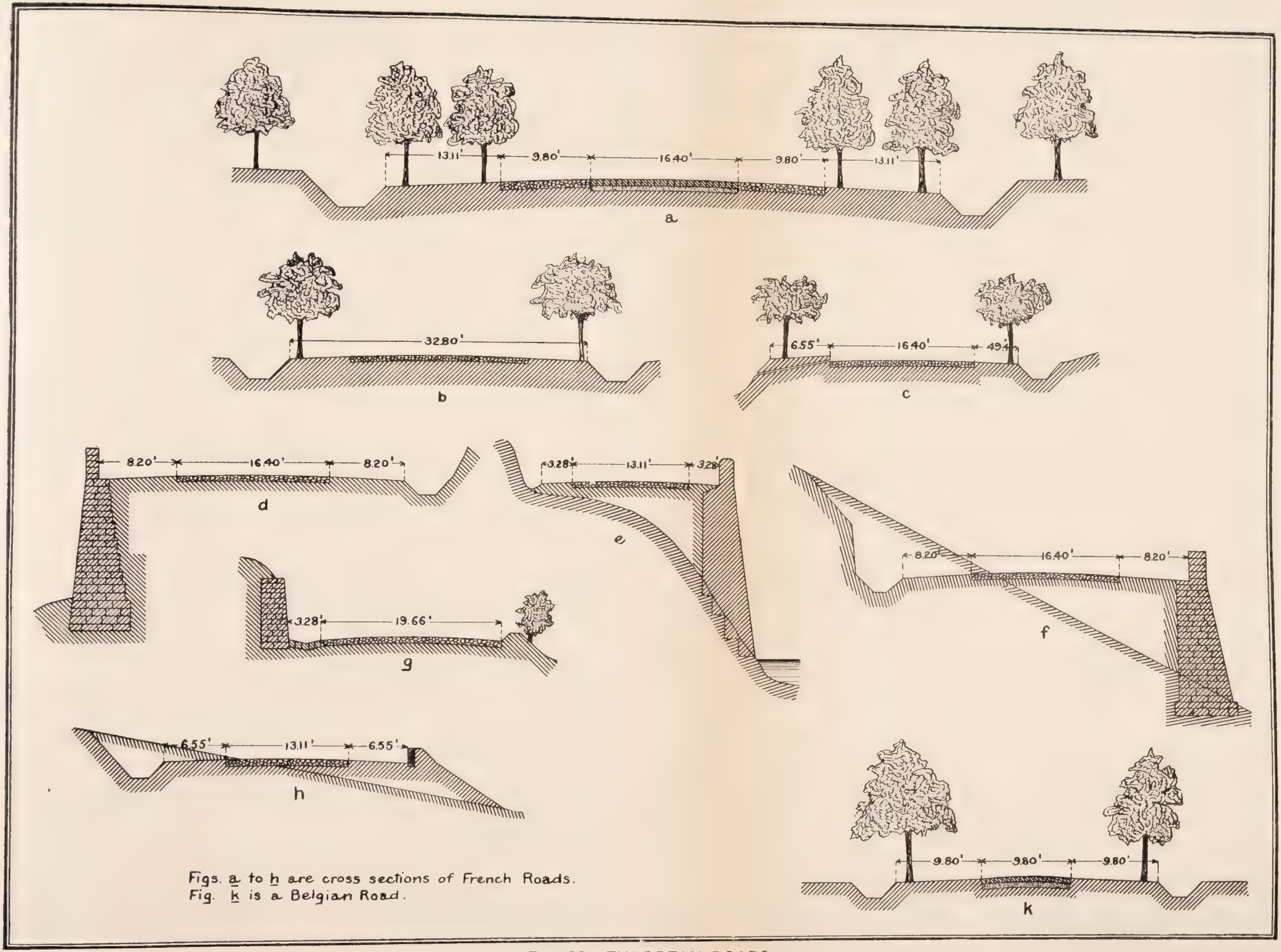


Fig. 88. EUROPEAN ROADS.

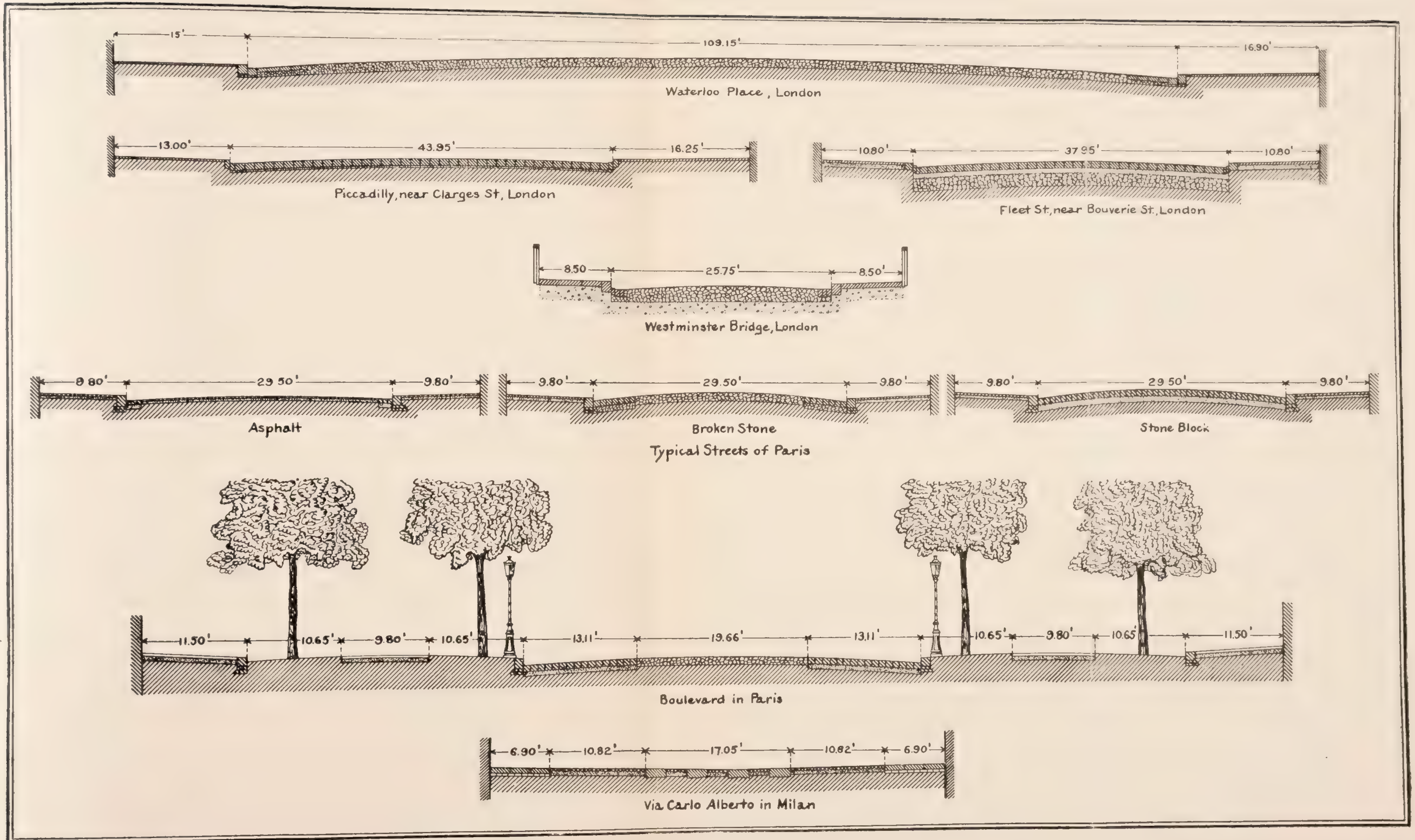


Fig. 89. EUROPEAN STREETS.

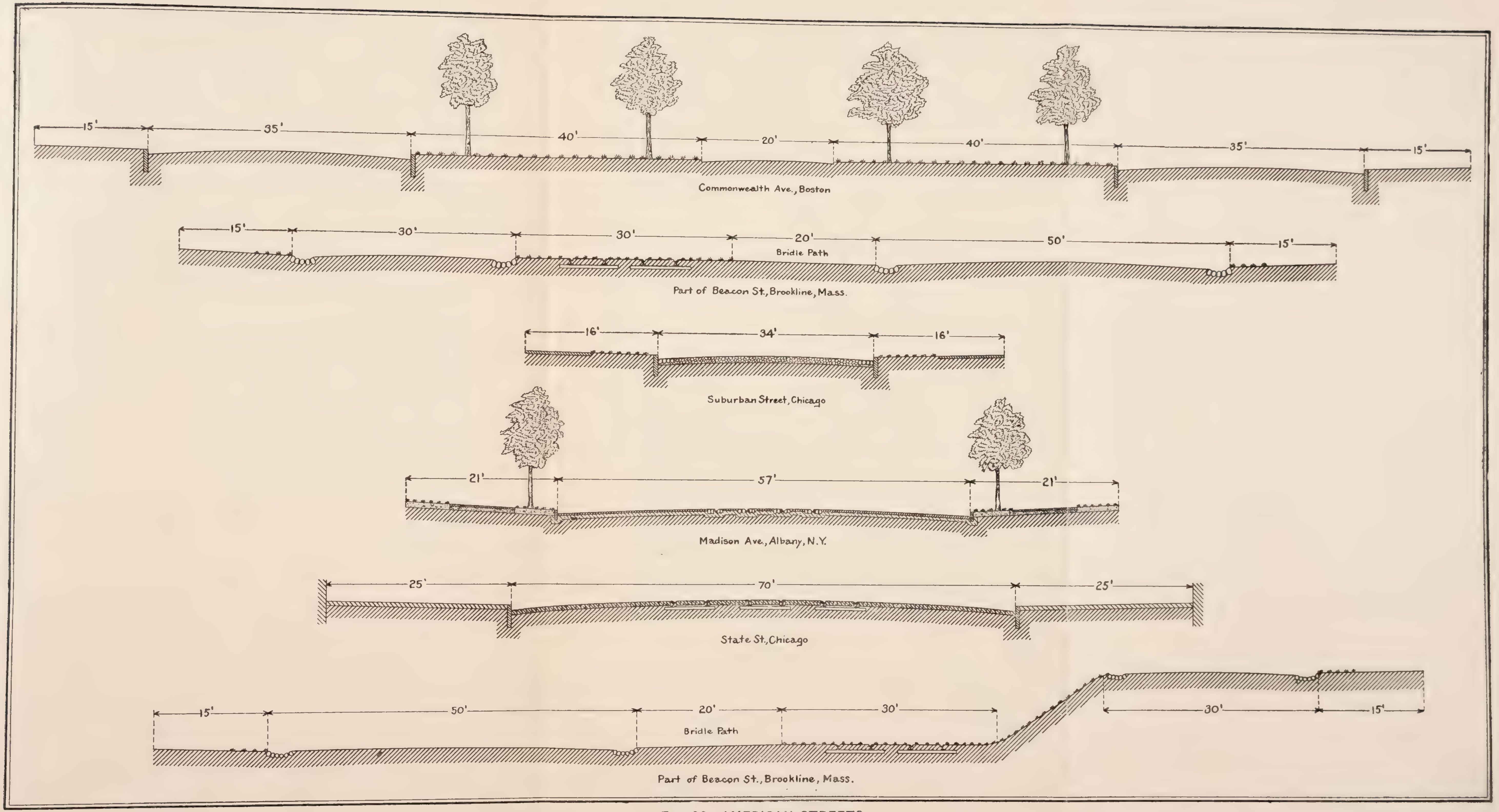


Fig. 90. AMERICAN STREETS.

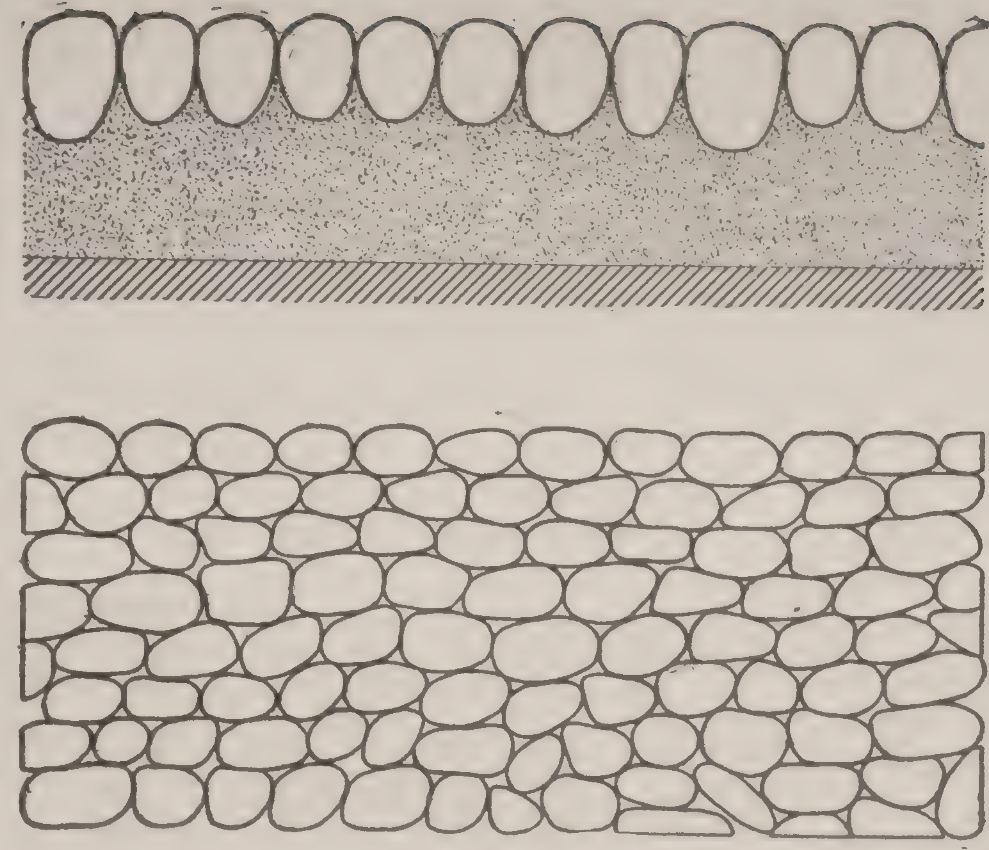


Fig. 91. COBBLE-STONE PAVEMENT.

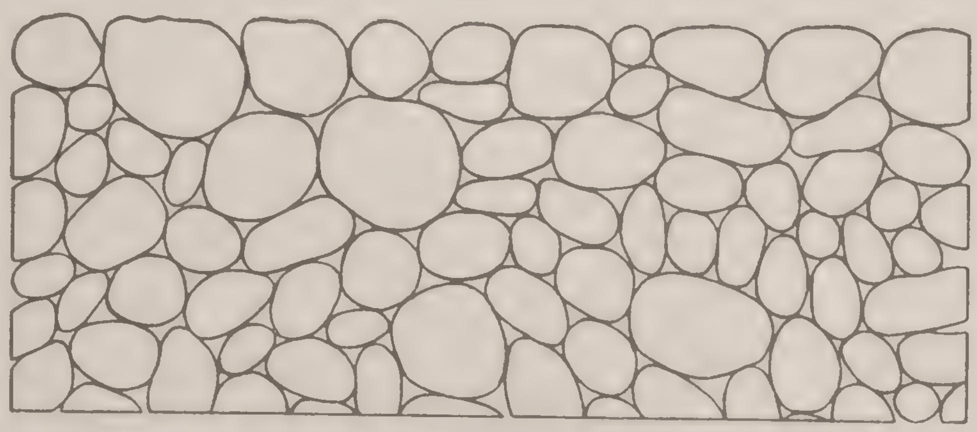


Fig. 92. COBBLE STONE PAVEMENT.

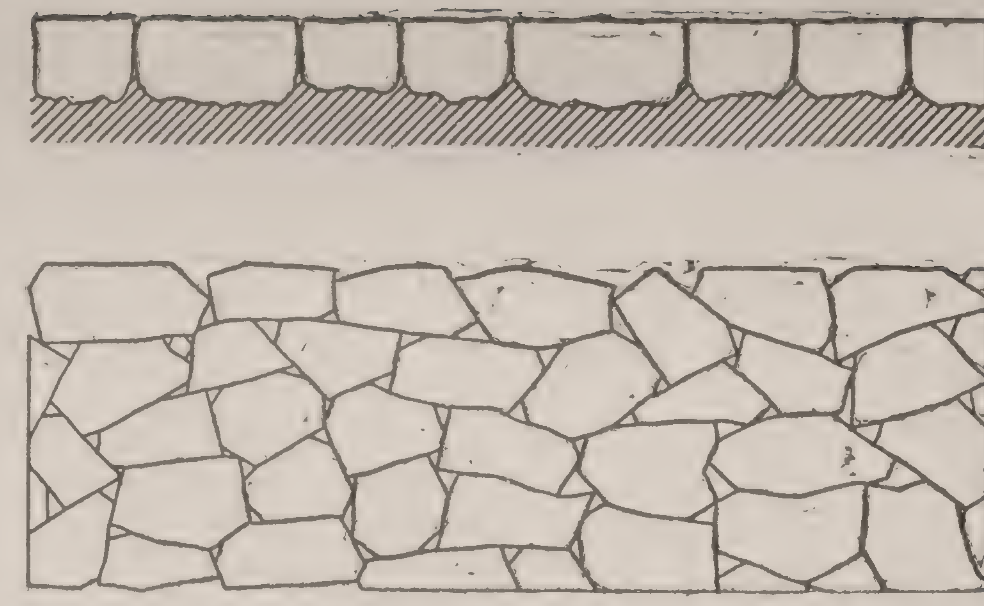


Fig. 93. RUBBLE-STONE PAVEMENT.

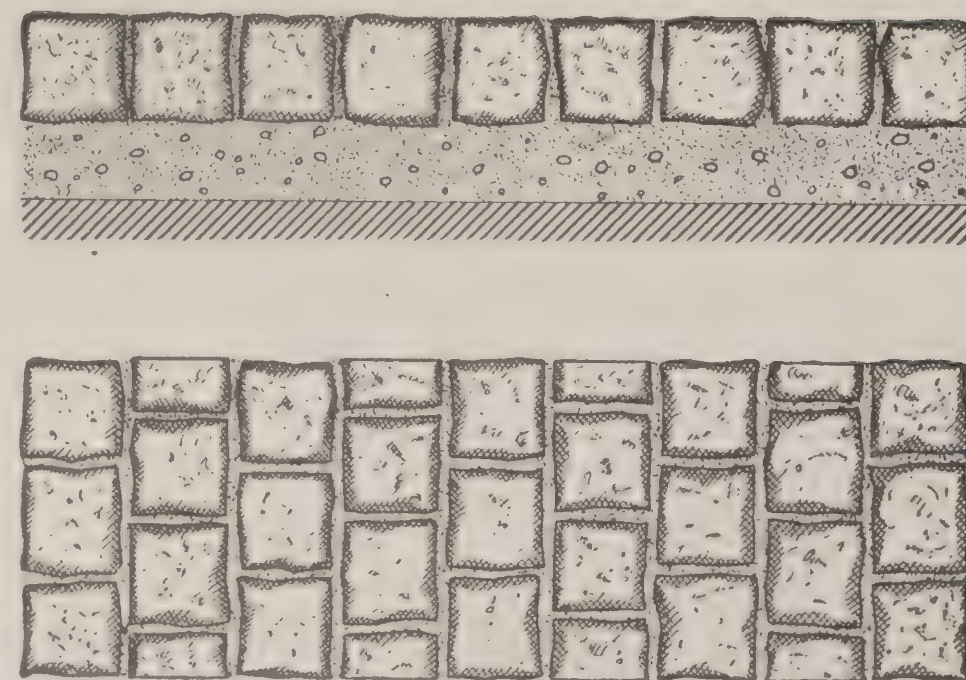


Fig. 93a. BELGIAN BLOCK PAVEMENT.

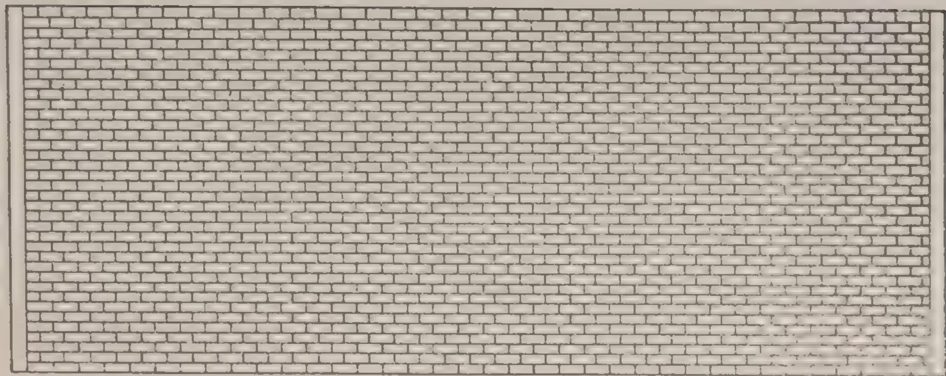


Fig. 94.

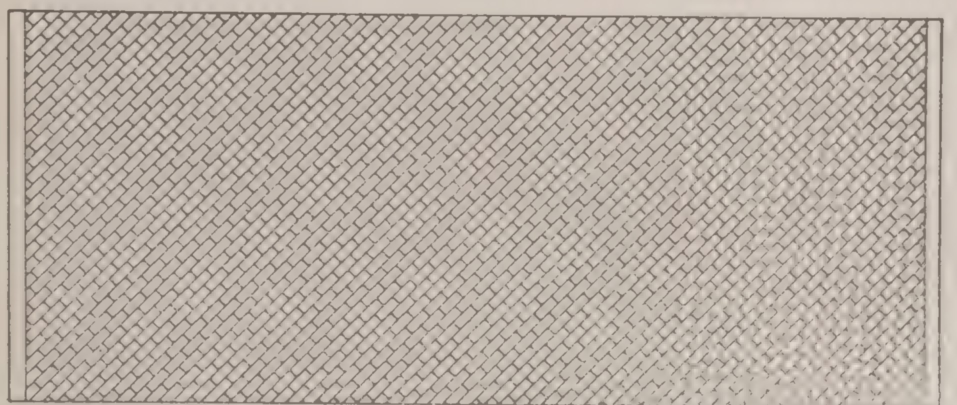


Fig. 95.

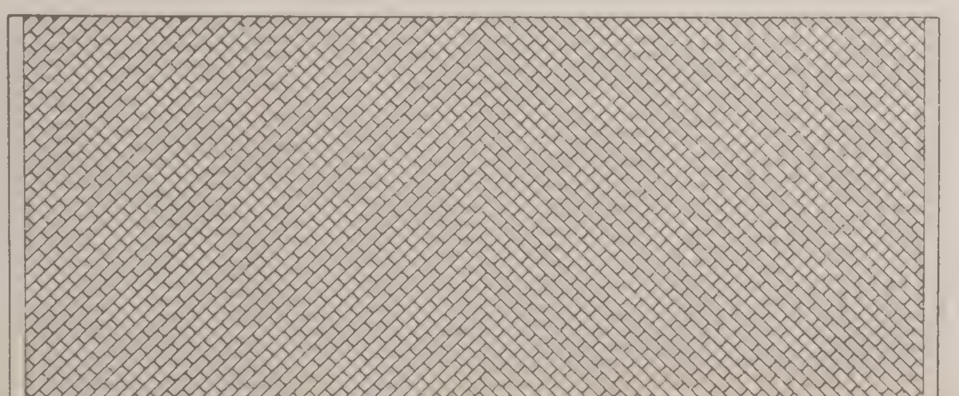


Fig. 96.

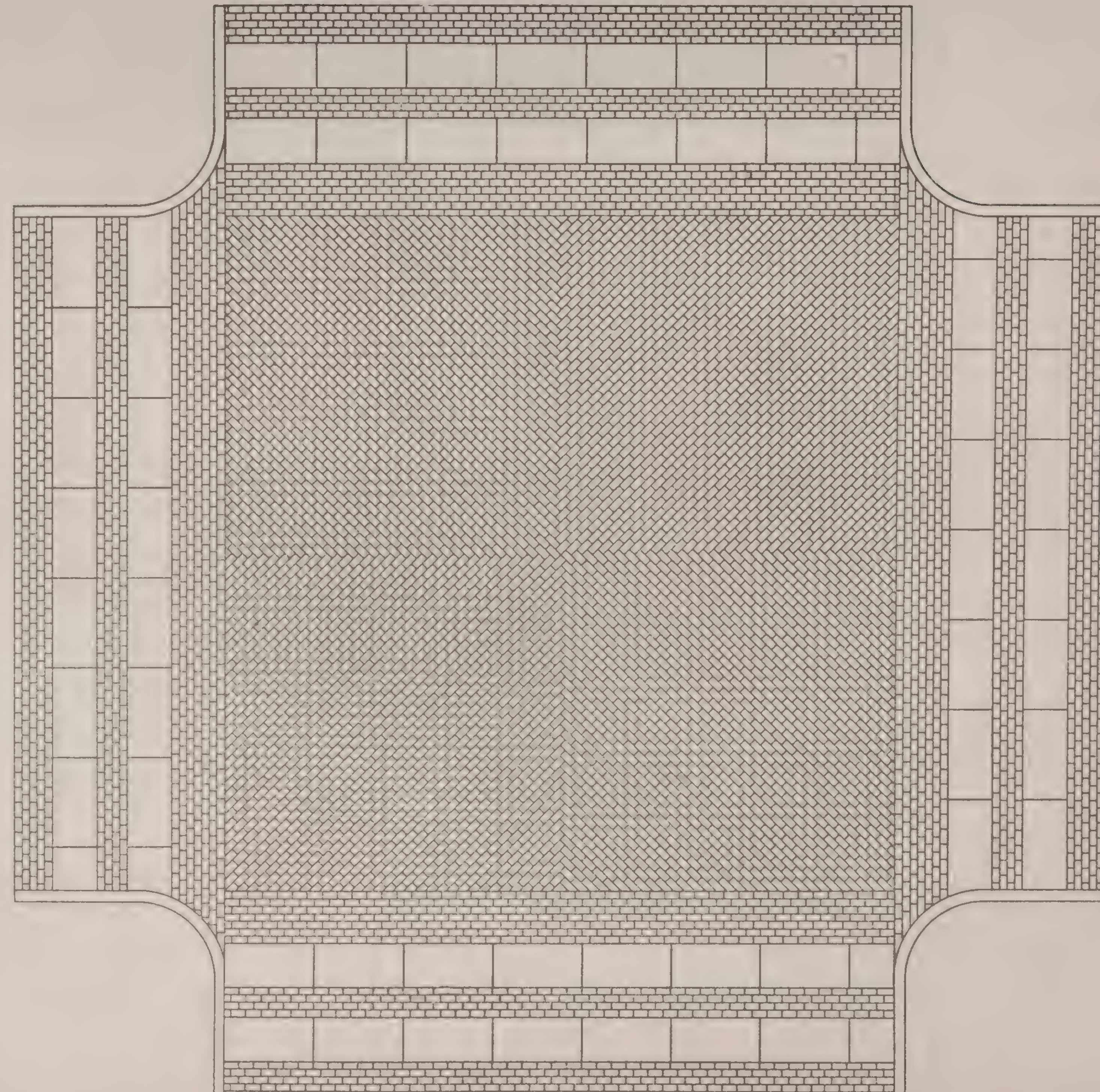


Fig. 97.

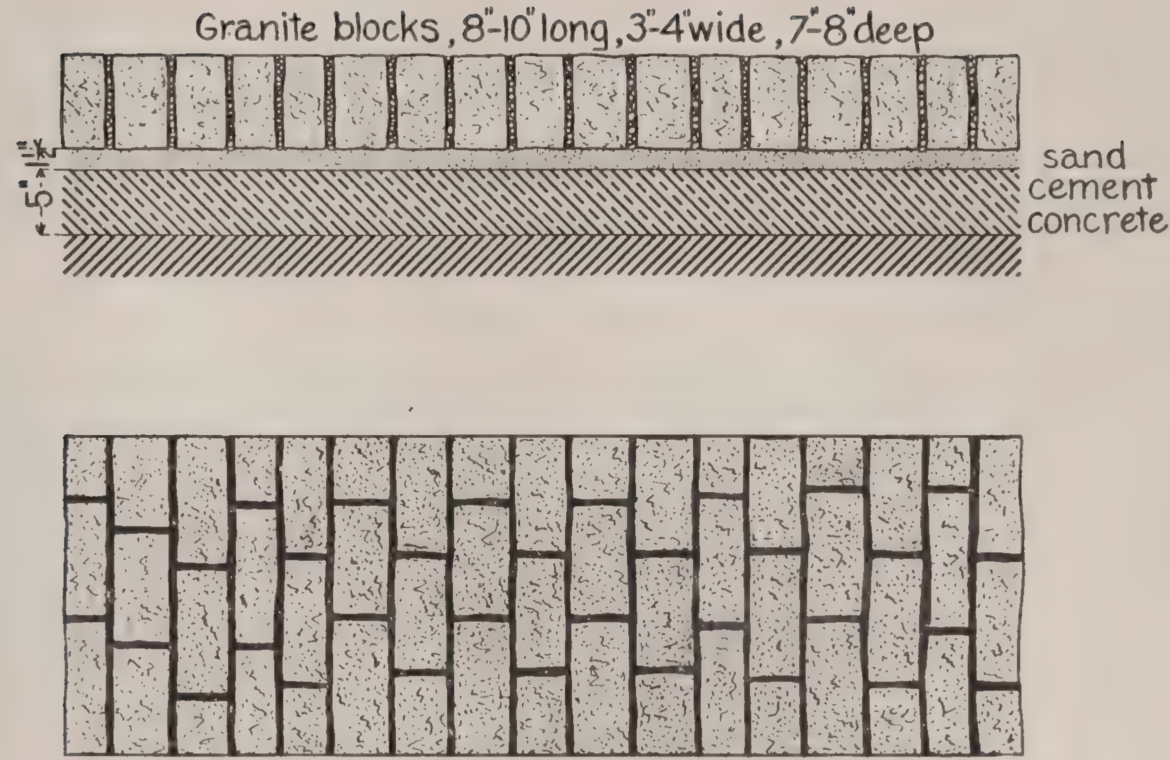


Fig. 98. PROVIDENCE, R. I.

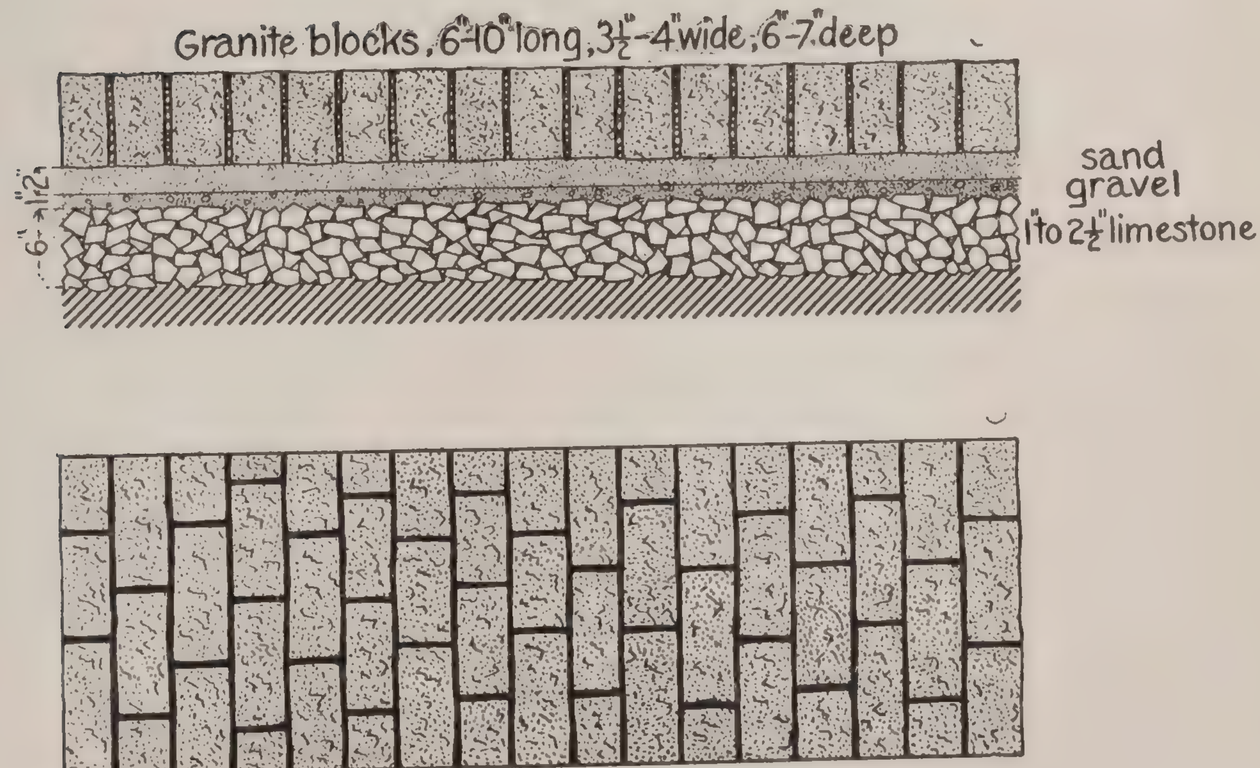


Fig. 99. CHICAGO, ILL.

GRANITE BLOCK PAVEMENTS.

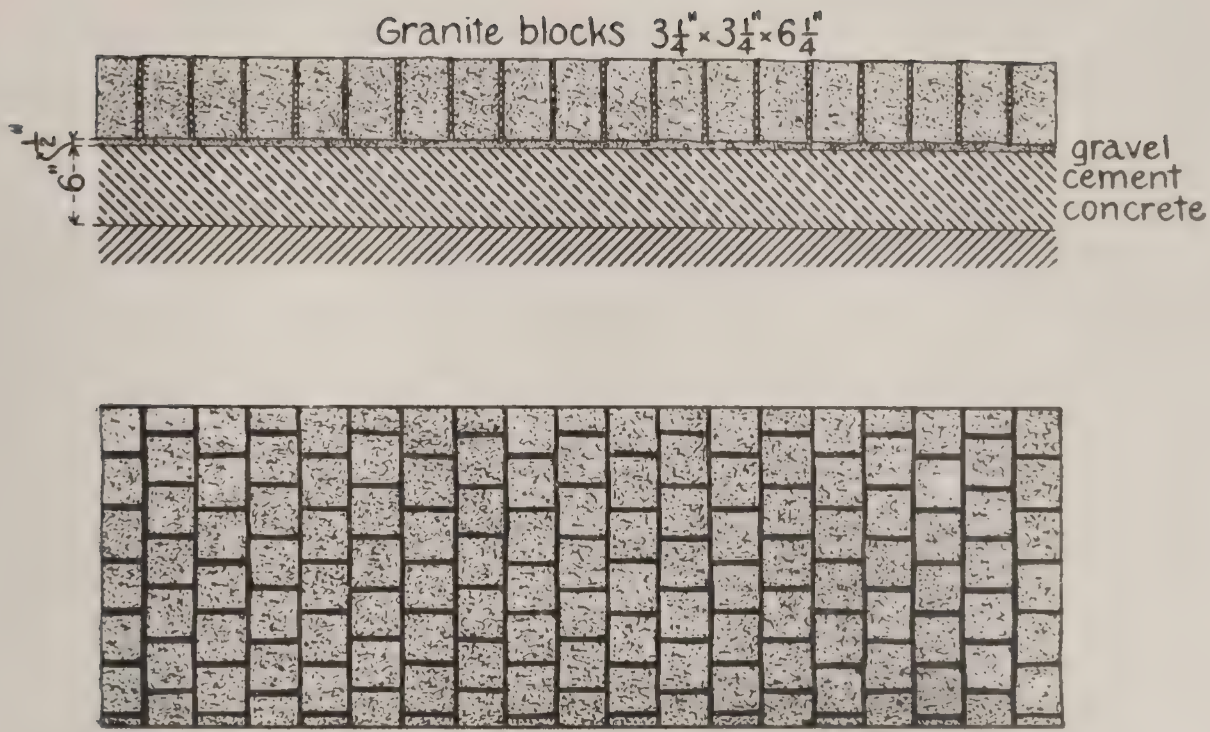


Fig. 100. LIVERPOOL, FIRST CLASS.

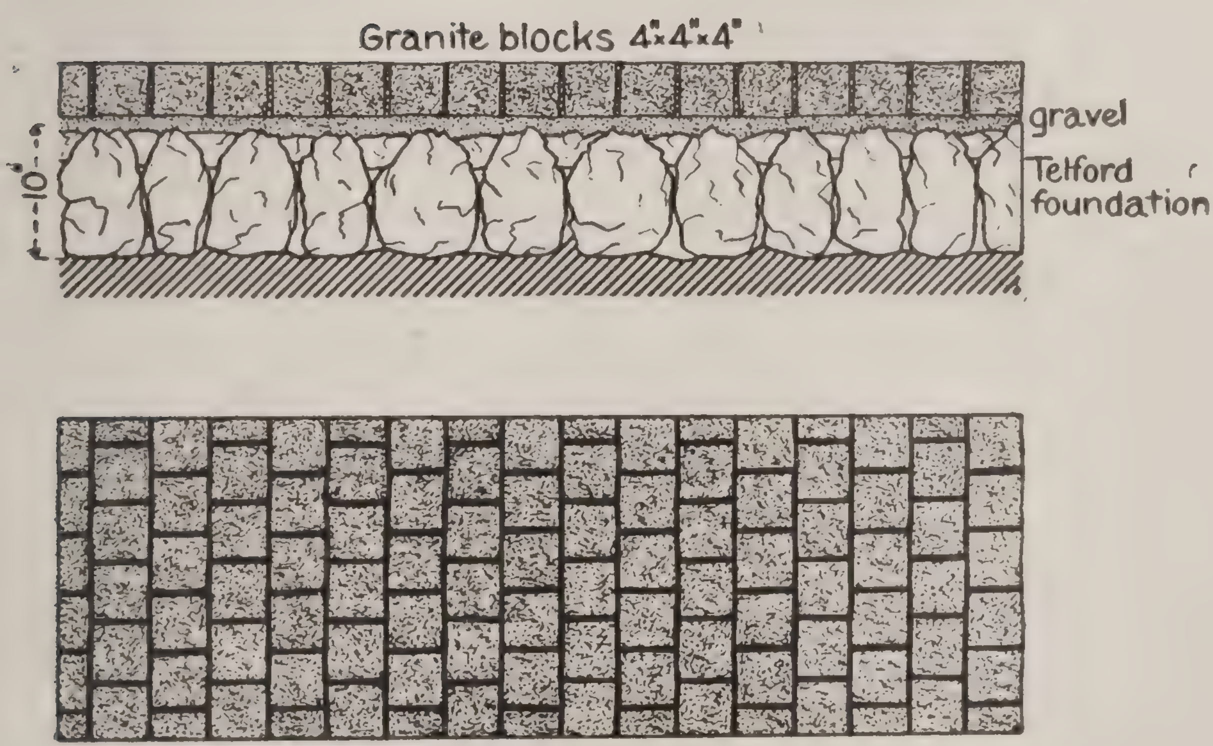


Fig. 101. LIVERPOOL, THIRD CLASS.

GRANITE BLOCK PAVEMENTS.

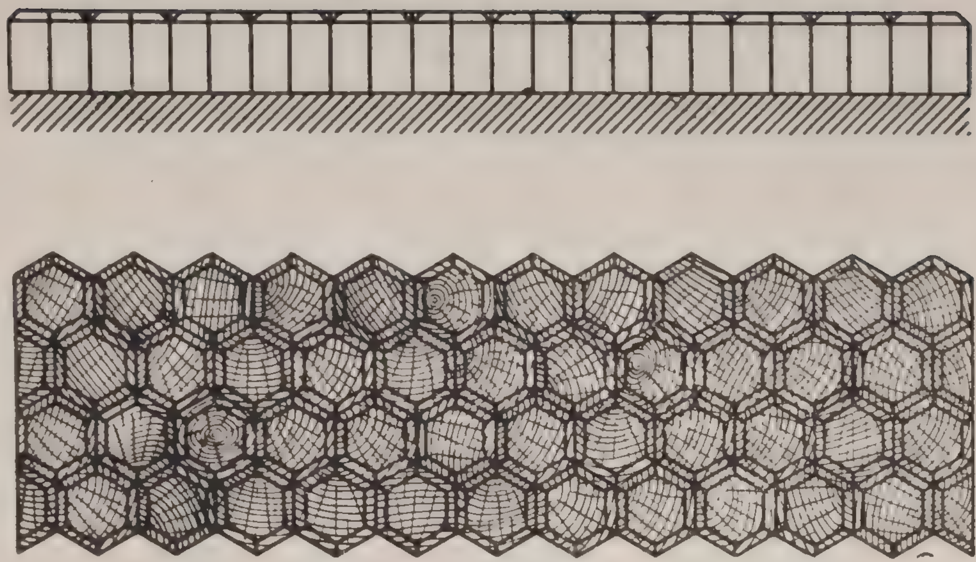


Fig. 102. STEAD'S.

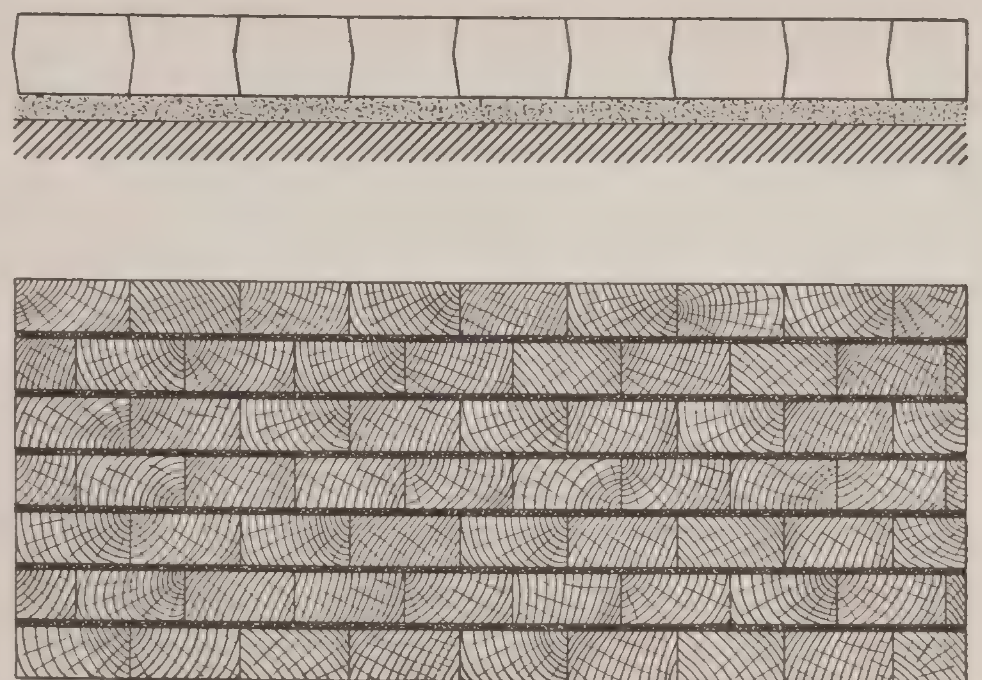


Fig. 103. CAREY'S.

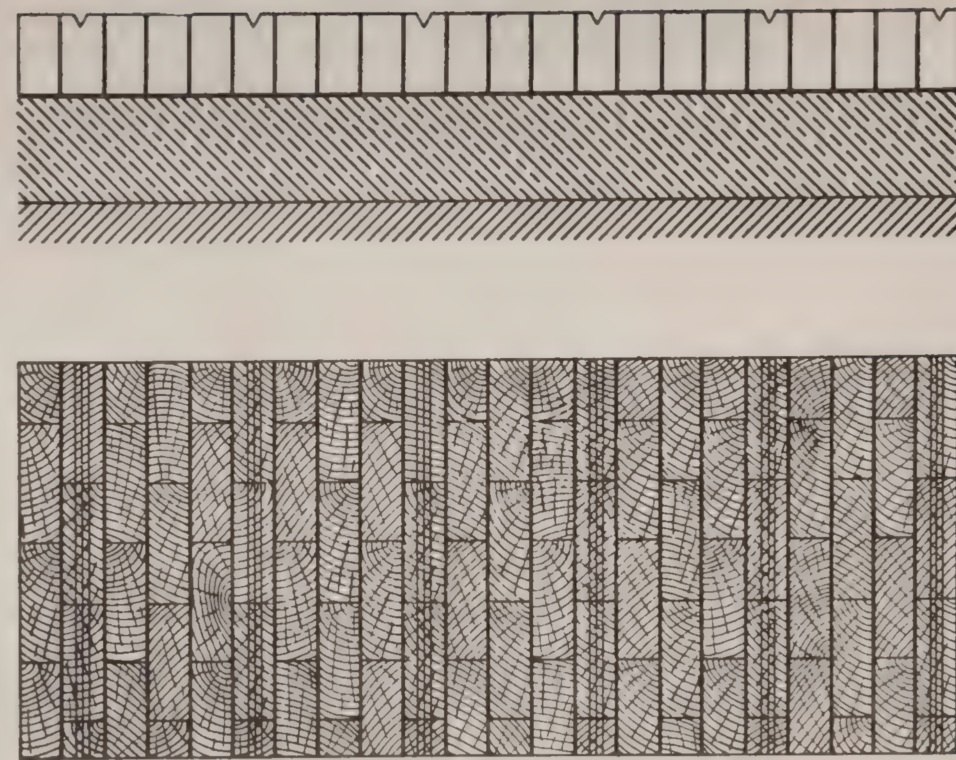


Fig. 108. HENSON'S.

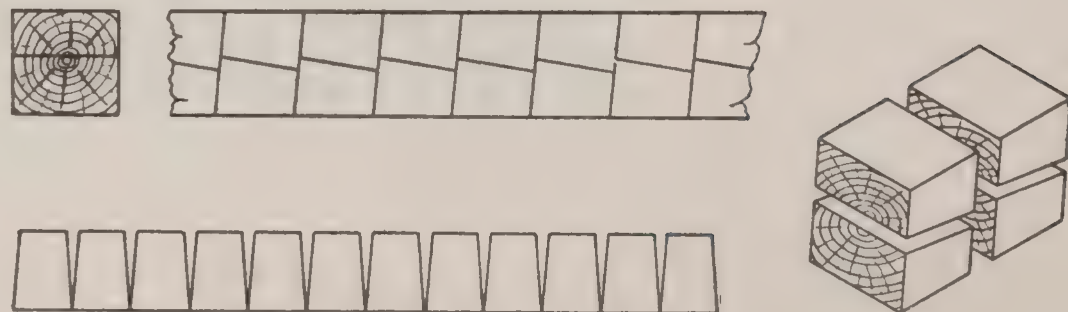


Fig. 104. CLARK'S.

WOOD BLOCK PAVEMENTS.

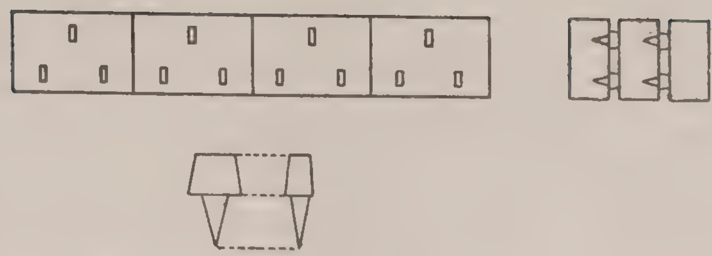


Fig. 105.

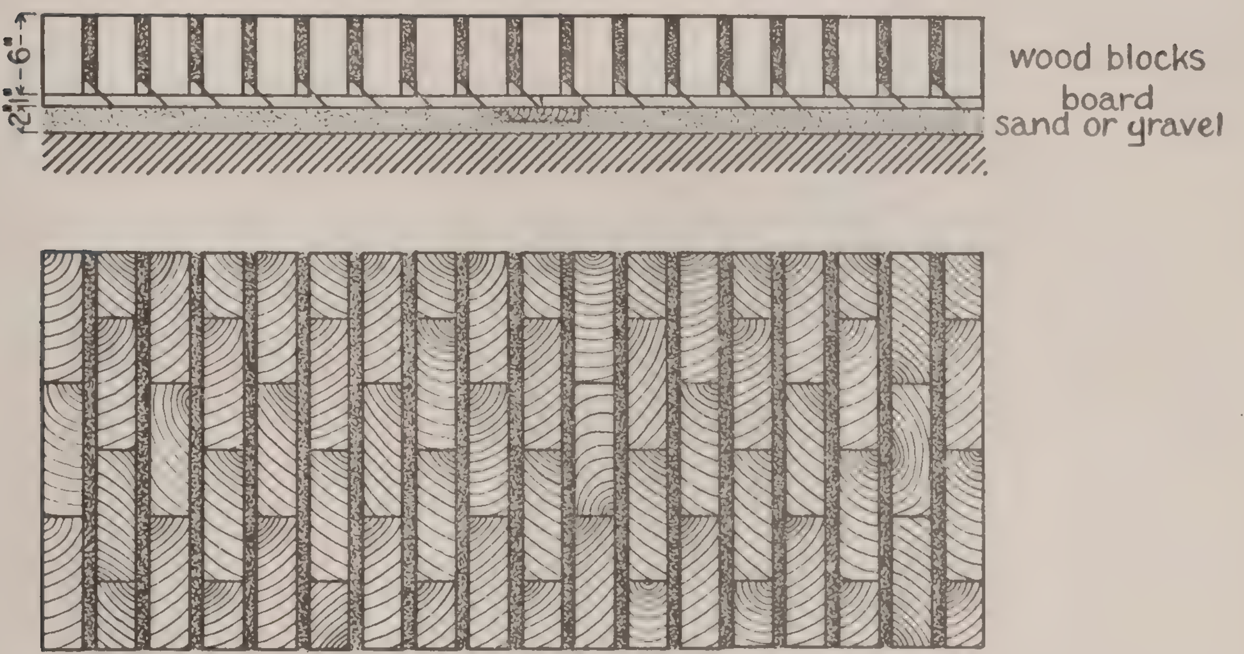


Fig. 106. NICHOLSON.

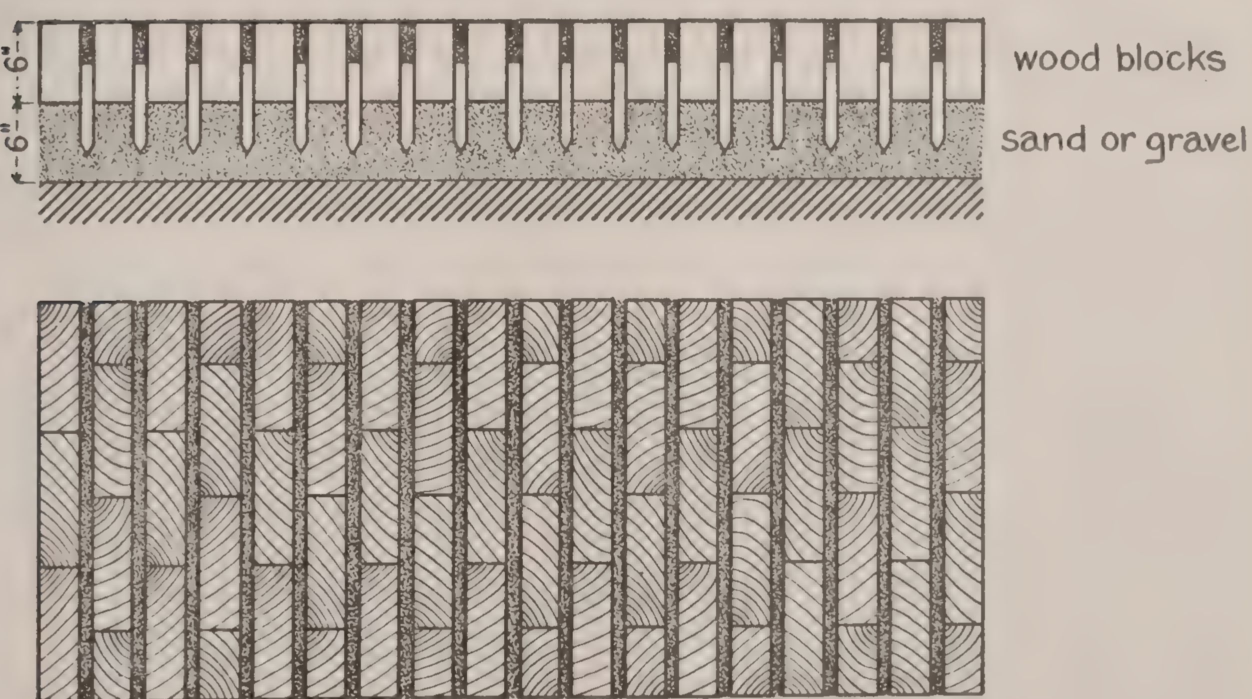


Fig. 107. STOWE.

WOOD BLOCK PAVEMENTS.

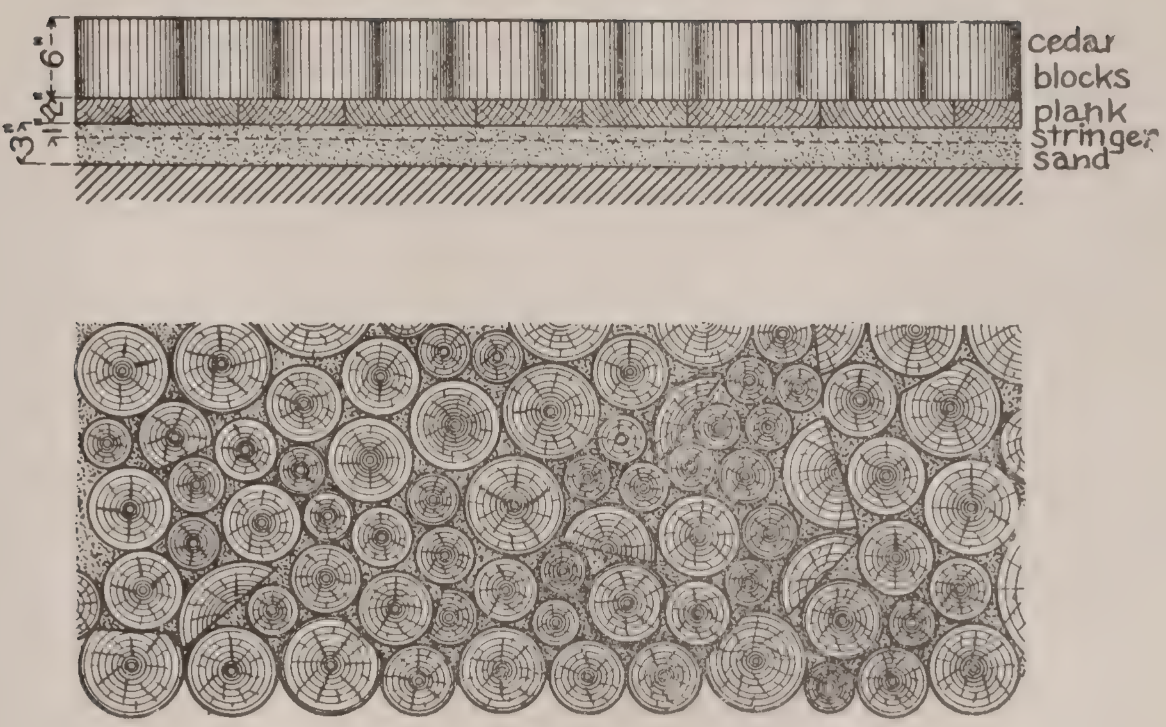


Fig. 109. CHICAGO.

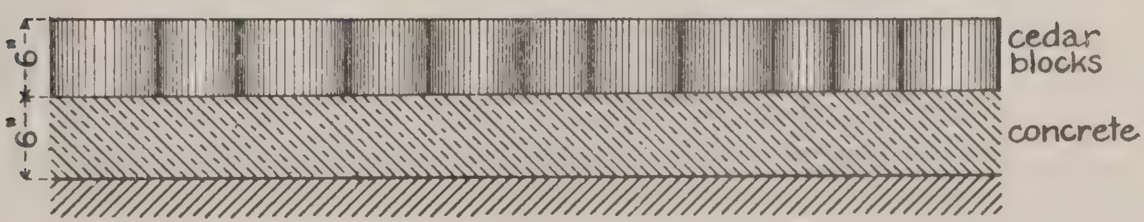


Fig. 110. DULUTH.

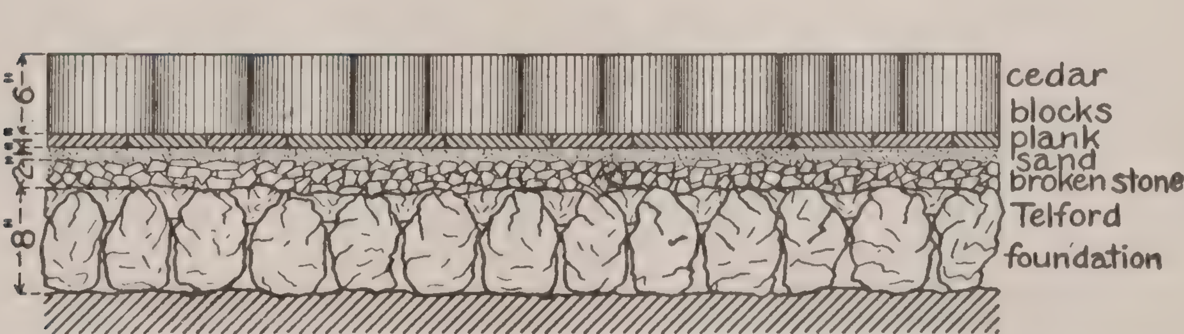


Fig. 111. DULUTH.

WOOD BLOCK PAVEMENTS.

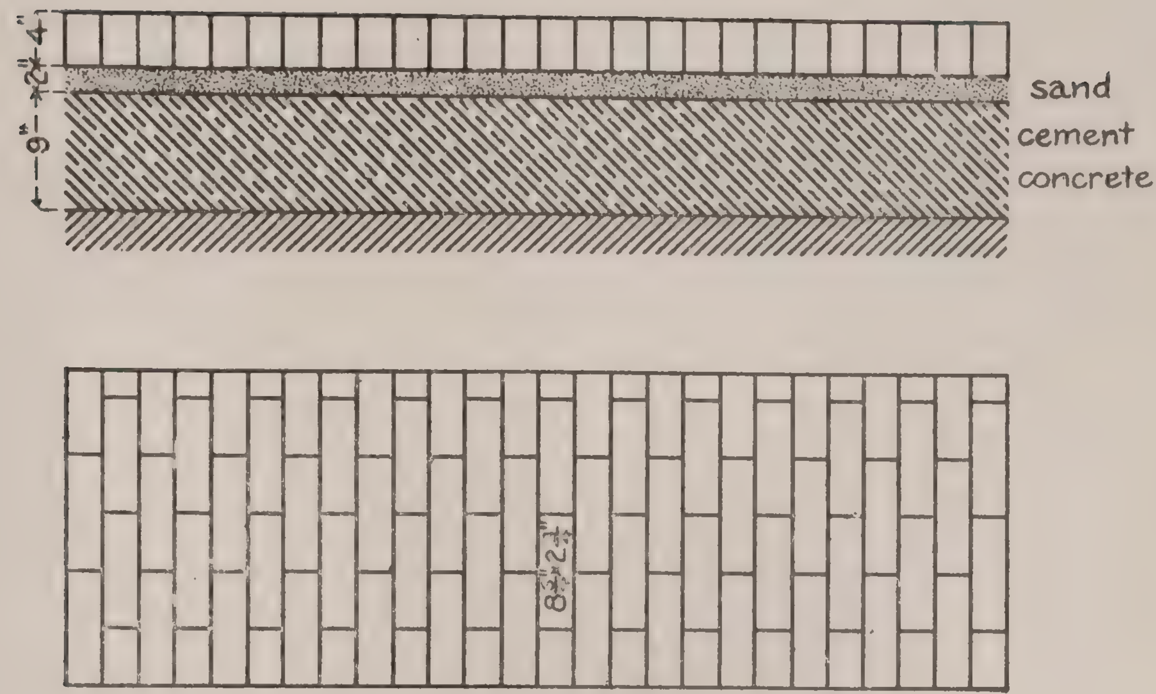


Fig. 112. MEMPHIS, TENN.

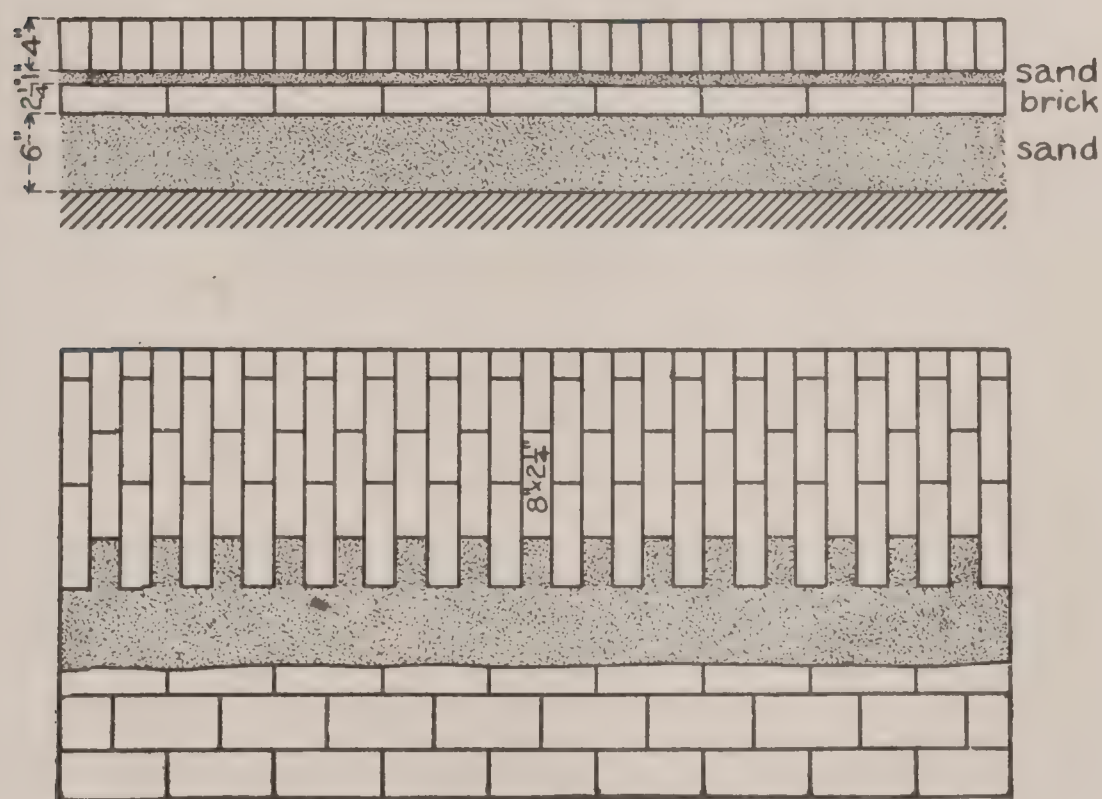


Fig. 113. TOPEKA, KAN.

BRICK PAVEMENTS.

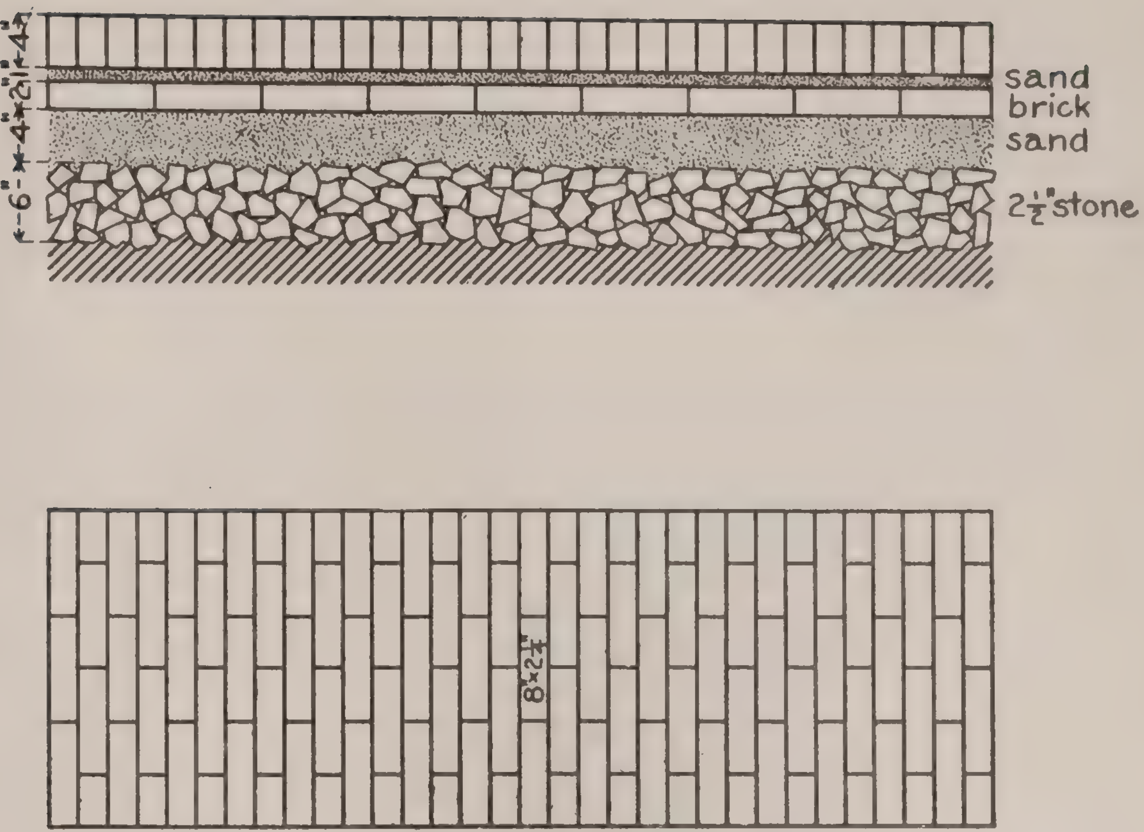


Fig. 114. DAVENPORT, IA.

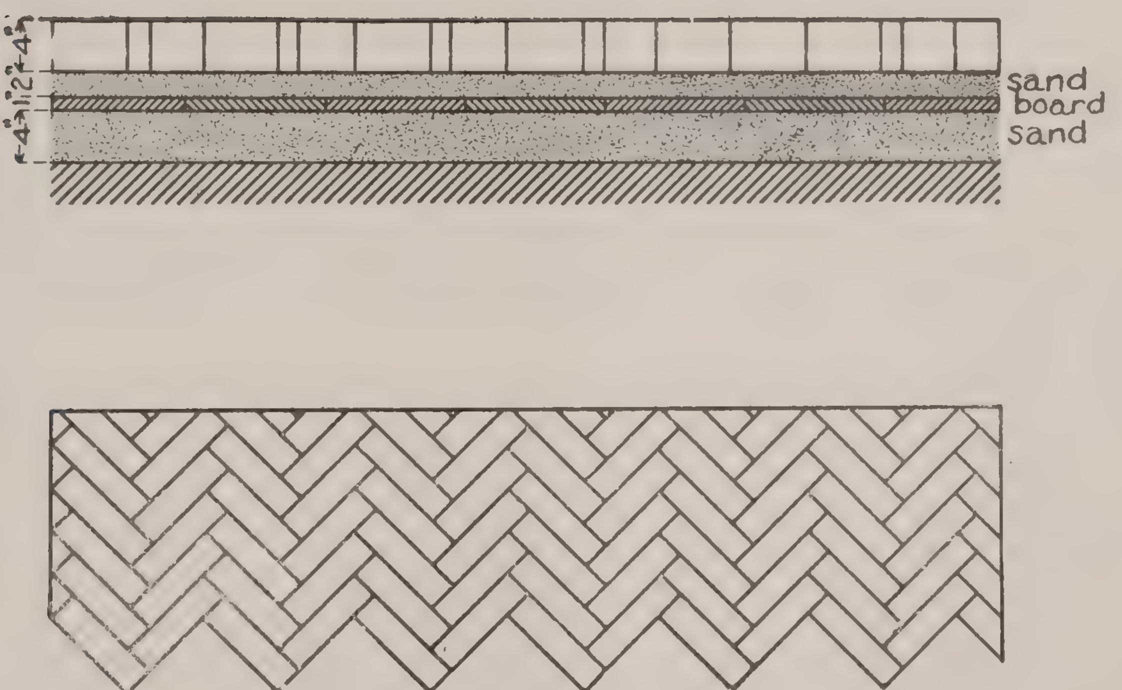


Fig. 115. HALE PATENT.

BRICK PAVEMENTS.

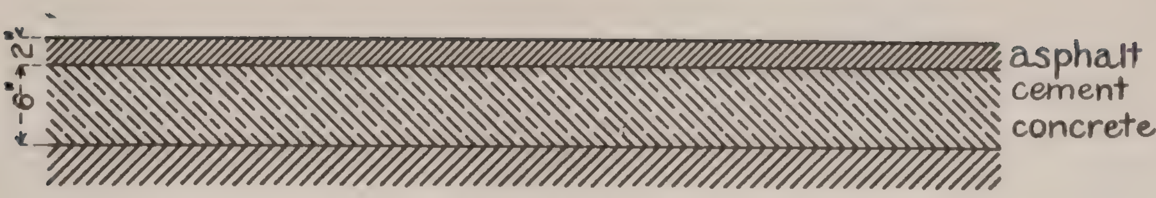


Fig. 116. ROCK ASPHALT.

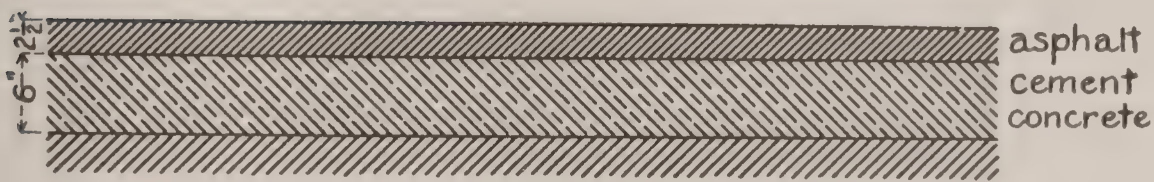


Fig. 117. TRINIDAD ASPHALT.

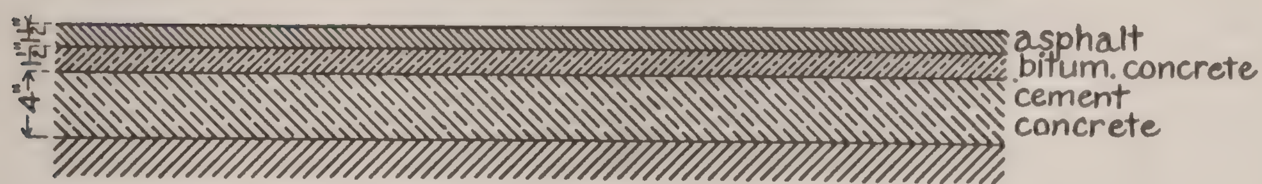


Fig. 118. TRINIDAD ASPHALT.

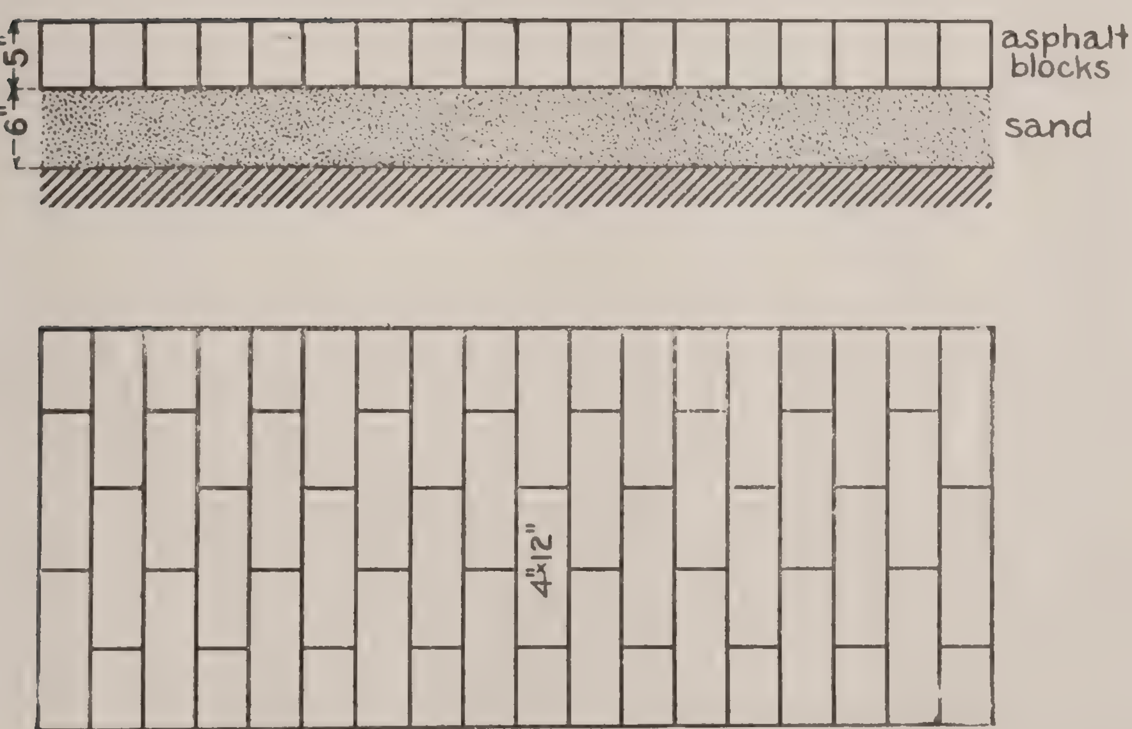


Fig. 119. ASPHALT BLOCKS.

ASPHALT PAVEMENTS.

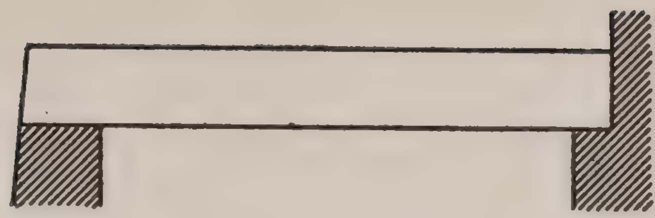


Fig. 122. STONE SLAB.

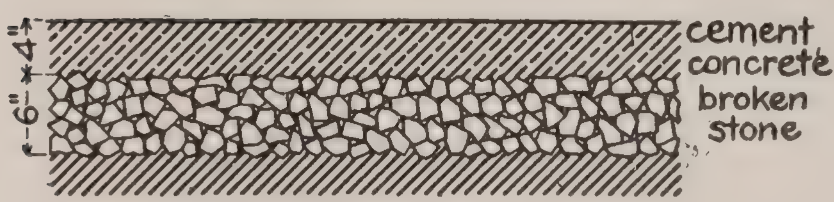


Fig. 123. CONCRETE.

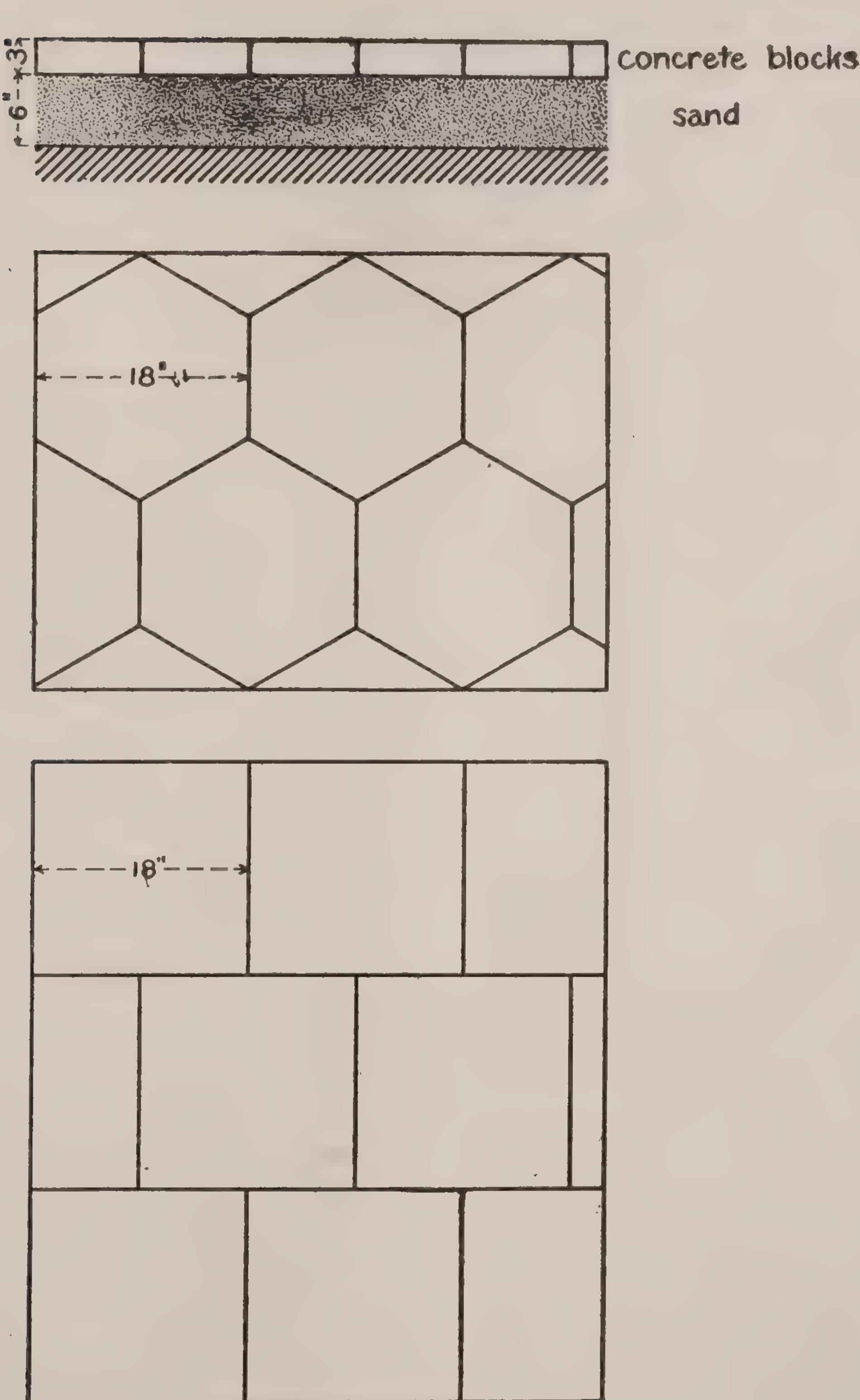


Fig. 124. CONCRETE BLOCKS.

SIDEWALKS.

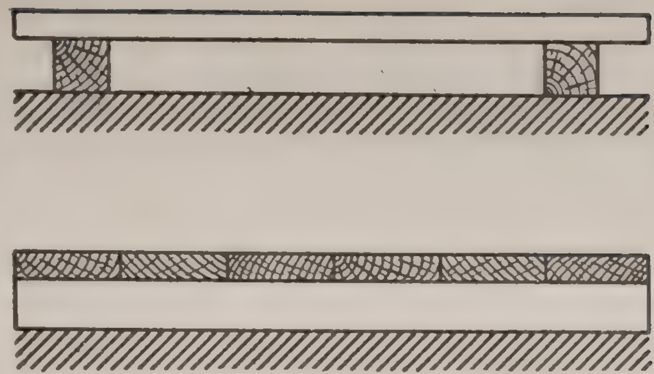


Fig. 120. PLANK.

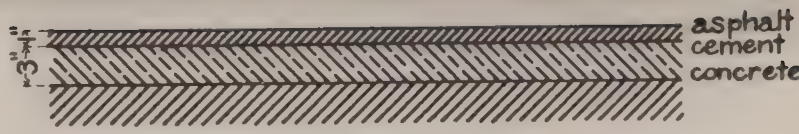


Fig. 125. SHEET ASPHALT.

Fig. 127. COAL TAR.

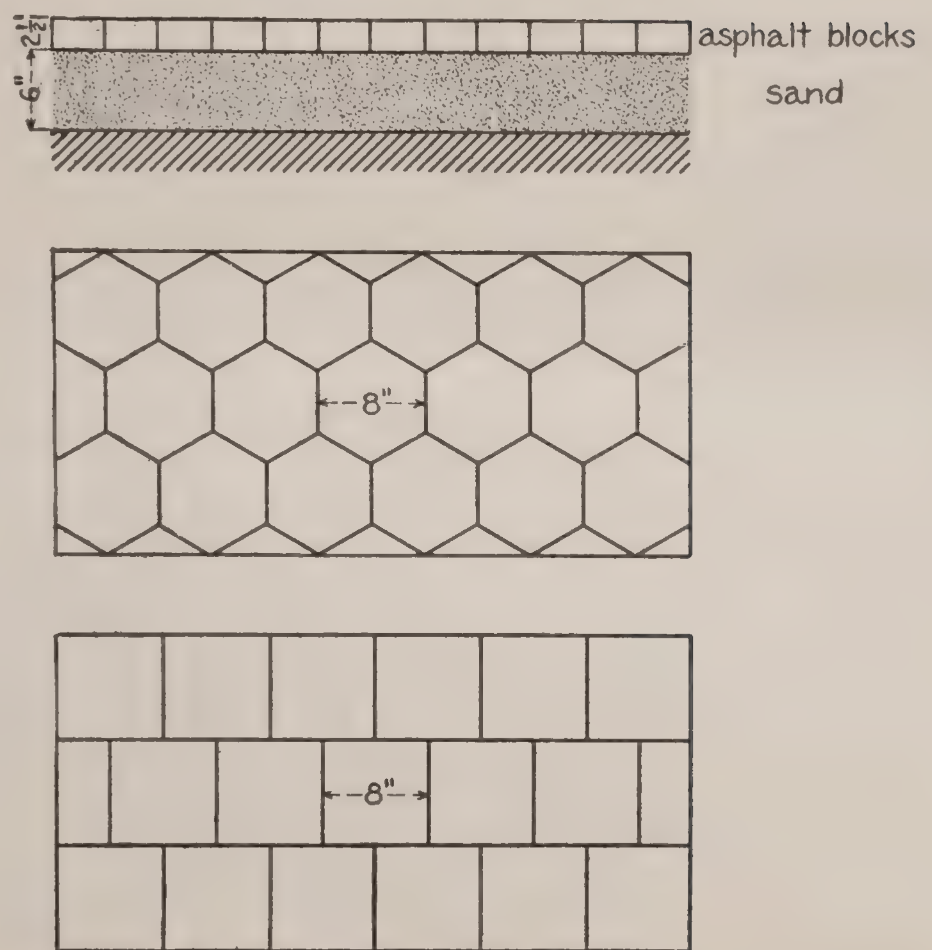


Fig. 126. ASPHALT BLOCKS.

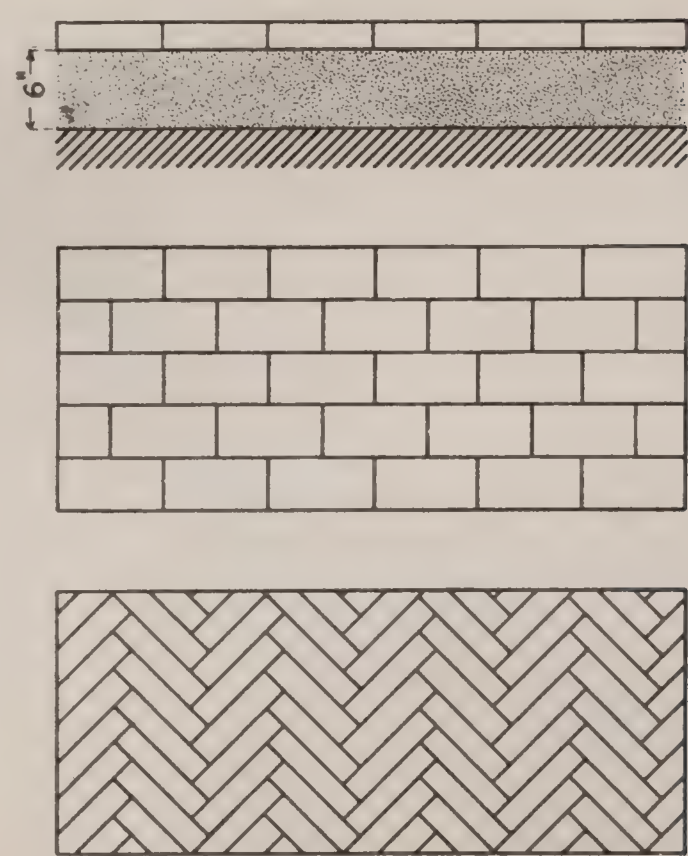


Fig. 121. BRICK.

SIDEWALKS.

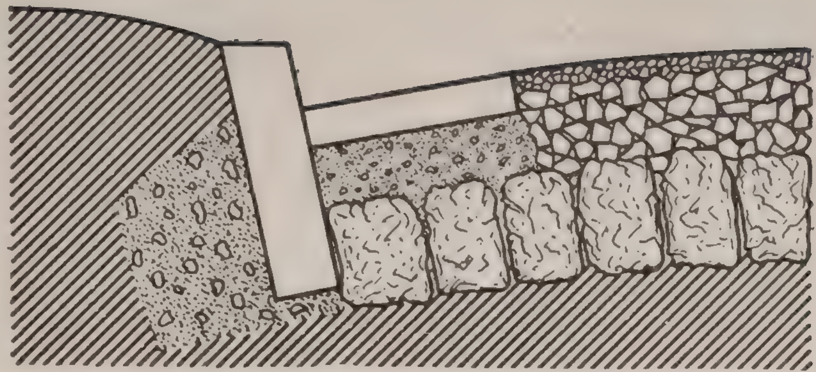


Fig. 128.

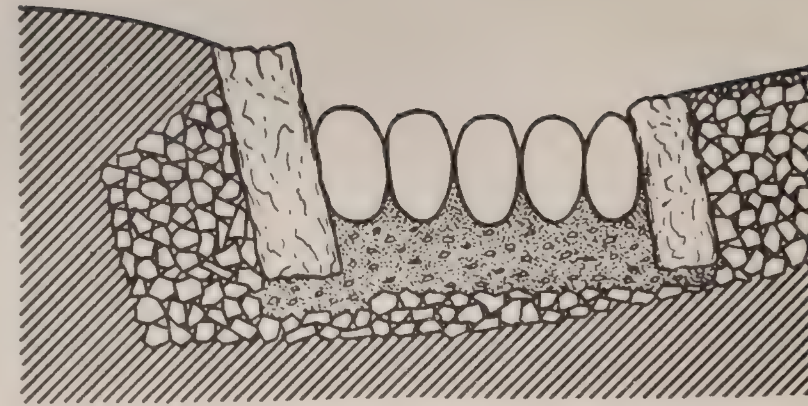


Fig. 129.

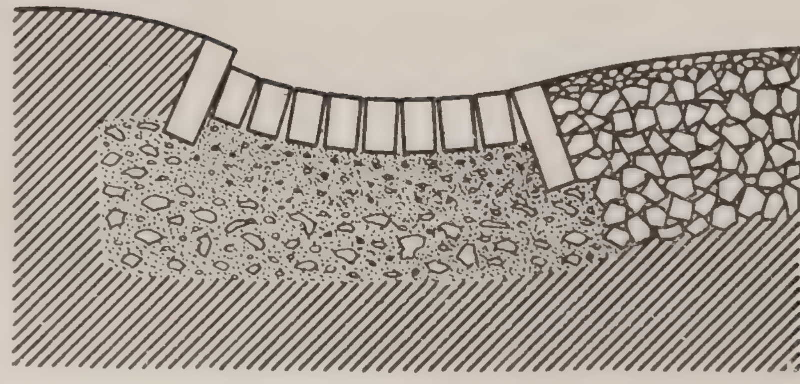


Fig. 130.

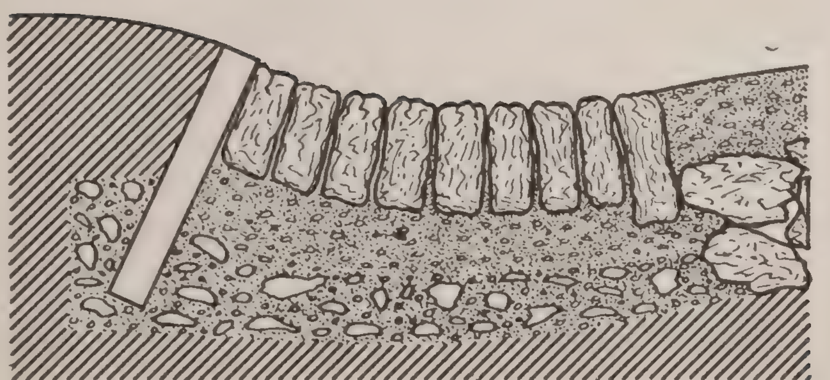


Fig. 131.

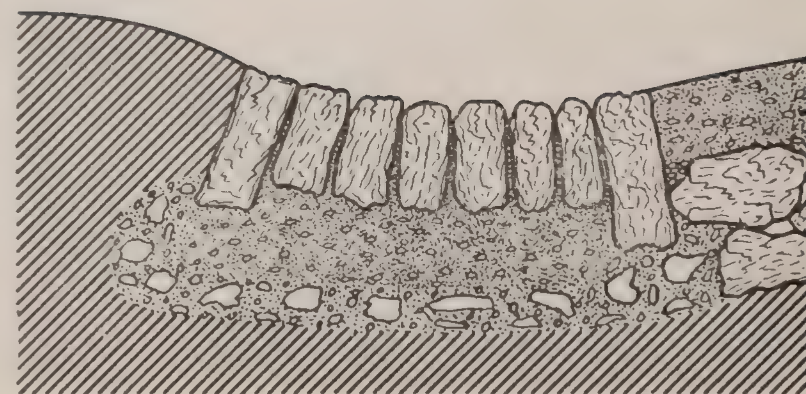


Fig. 132.

CURBS AND GUTTERS, CENTRAL PARK, NEW YORK.

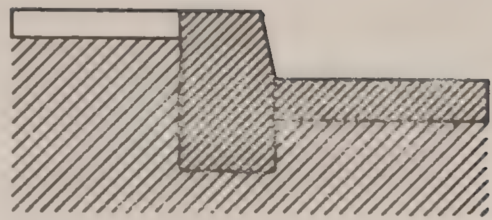


Fig. 134. LIVERPOOL.

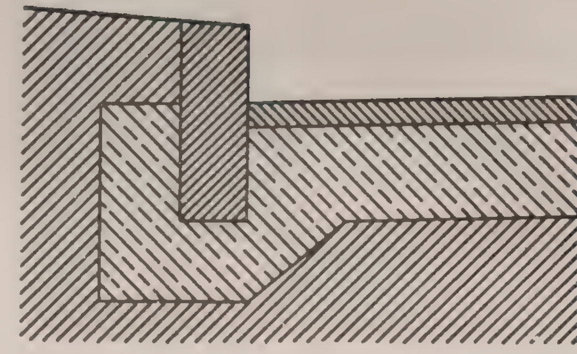


Fig. 135. ALBANY.

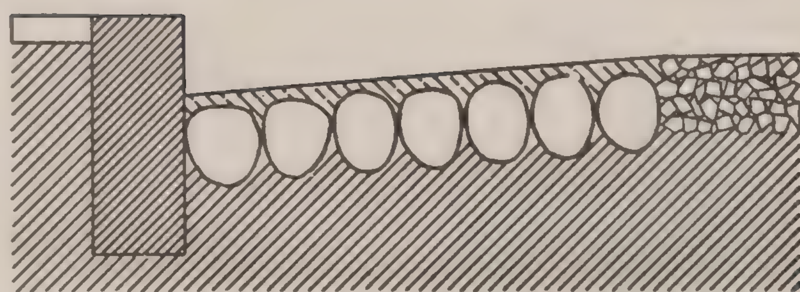


Fig. 133. PROVIDENCE.

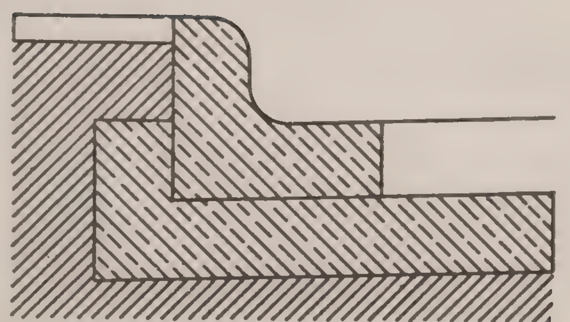


Fig. 136. DULUTH.

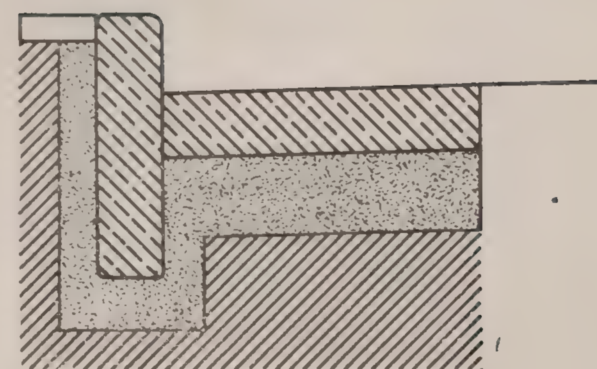


Fig. 137. TOPEKA.

CURBS AND GUTTERS.